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HIGH TIBIAL OSTEOTOMY
FOR GONARTHROSIS

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I. INTRODUCTION

Osteotomy at the knee joint for correction of deformity was introduced long before the era of anti- or aseptic surgery. In classic orthopaedics, however, the operation was employed mainly for correction of congenital and acquired deformities – above all for rickets. According to Helal (1965) osteotomy for treatment of gonarthrosis was performed in some cases in the 1940s by McMurray. At a meeting with the Sheffield Regional Orthopaedic Club in 1958 Jackson reported the results of 14 osteotomies in knee joints with the lateral type of gonarthrosis. This was the first published series of osteotomy in gonarthrosis followed by Jackson and Waugh (1961) and Bouillet and Van Gaver (1961). Since then osteotomy has become a widely accepted method for treatment of gonarthrosis (Wardle 1962, Gariépy 1964, Coventry 1965, Helal 1965, Ramadier and D'Aubigné 1965, Debeyre and Patte 1966, Bauer et al. 1969, Jackson et al. 1969, Harris and Kostuik 1970, Gagnaire et al. 1970, Artigou 1971, Appel And Friberg 1972, Coventry 1973, Shoji and Insall 1973).

The results have generally been favourable. However, the case reports have been few, and comparison of operative techniques are essentially impossible because of different methods of pre- and postoperative assessment of the surgical results. Indeed, the very nature of the clinical condition has often not been described, e.g. in terms of age, sex, type and degree of arthrosis. The effect of osteotomy in osteoarthrosis has been debated; the biomechanical factor of unloading the diseased articulation is certainly important (Maquet et al. 1967, Bauer et al. 1969). The osteotomy also has an effect on the intra-osseous pressure (Helal 1965), and some authors have claimed that the operation starts a process of healing which also affects the articular cartilage (Chapchal 1973).

The purpose of this investigation was to analyse the effect of high tibial osteotomy in different kinds, types and degrees of gonarthrosis, to assess the correlation between the results of operation and the correction of the deformity, and, finally, to define the indications of high tibial osteotomy for gonarthrosis as compared to the total endoprosthesis.

A. PRESENT CONCEPTS OF GONARTHROSIS

1. Definition

A chronic, degenerative, non-inflammatory condition of the knee joint with primary destruction and loss of articular cartilage with secondary changes in the juxta-articular bone in the form of subchondral sclerosis and bone loss, i.e. attrition (Ahlbäck 1968). The following synonyms reflect earlier concepts of etiology or attempts at distinguishing between primary arthrosis and arthrosis secondary to arthritis: osteoarthritis or osteoarthrosis of the knee, arthrosis deformans genu.

2. Etiology

Gonarthrosis may occur secondary to intraarticular fracture of the knee, congenital or acquired postural deformity, bacterial or rheumatoid arthritis, and a host of metabolic abnormalities which may affect the knee, e.g. hemophilia, gout, psoriasis, villinodular arthritis and pyrophosphate synovitis - the newly described condition osteonecrosis of the knee (Ahlbäck et al. 1968) may well be assigned to the latter group. However, in today's clinical practice, most cases of gonarthrosis develop without evidence of etiologic factors other than female preponderance and age correlation - idiopathic or primary gonarthrosis is rarely seen before age 50 and the more severe cases are usually over 65 years of age.

3. Morbidity

Gonarthrosis is a common disease among older people, but the incidence has not been exactly defined because of the lack of diagnostic criteria. Thus, Heine (1926) who recorded the degenerative microscopic findings in 1 000 autopsy specimens, found the incidence of what he called arthrosis to rise with age to 100 % in individuals over 80 years old. However, he did not correlate his findings with clinical symptoms, and was, therefore, not able to distinguish between osteoarthrosis sui generis and the normal physiologic aging of the cartilage. Based on modern concepts of the radiographic diagnosis of gonarthrosis (Ahlbäck 1968), Danielsson and Hernborg (1970) calculated the minimum incidence of primary gonarthrosis in Malmö, Sweden. They found the incidence for women to rise from negligible below age 50 to 3 % at age 75. The incidence was higher in women than in men, and this difference rose with age.

4. Pathophysiology

The arthrotic process in the knee has earlier been thought to start in the femoro-patellar articulation, and later to progress to the other articulations of the knee

(Glimet 1963, Salter 1970). Based on this concept, osteotomy in gonarthrosis would constitute rational treatment only in cases secondary to varus or valgus deformity (Herbert et al. 1967). However, Bouillet and Van Gaver (1961) correlated their findings of lateral deformities in a series of gonarthrosis with Bragard's (1932) data on deformities of the knee in an unselected material of 4 200 individuals of various ages. They found a correlation between deviations in the frontal plane and gonarthrosis, and that in certain individuals the deviation was secondary to the arthrotic process. They concluded that in terms of development of arthrosis the different articulations of the knee were, to a certain extent, independent of each other. This fundamental quality of primary gonarthrosis to be focal and, thus, essentially located in only one of the two femoro-tibial articulations was clearly demonstrated by Ahlbäck (1968) who visualized the true articular space with the aid of radiograms obtained in standing position. Of 370 knees with primary arthrosis narrowing of the articular space at only one of the three articulations occurred in 317. Thus, only 15 % had narrowing of the articular space in more than one of the three articulations. Only two knees had narrowing in all three articulations, and four in both femoro-tibial articulations but not in the femoro-patellar articulation. The focal nature of the arthrotic process was confirmed by ^{85}Sr scintimetry (Bauer and Smith 1969); up-take of ^{85}Sr was higher than normal in those areas of osteoarthrotic knees where osteosclerosis was a predominant radiographic feature.

The asymmetrical loss of cartilage in gonarthrosis thus causes a deformity which leads to overloading of the articulation on the concave side of the deformity - this overloading in turn accelerates the arthrotic process.

5. Pain in gonarthrosis

That the appearance of deformity in gonarthrosis was associated with a typical pain pattern was noticed by Wardle (1962). Pain is the dominating symptom in gonarthrosis, and nearly always is the main indication for therapy. The pathophysiology of pain in gonarthrosis is not clearly understood. In many of the publications dealing with osteotomy in gonarthrosis there has been a clear tendency to a correlation between diminished pain and the reestablishment of a normal femoro-tibial angle (Ramadier et al. 1965, Debeyre and Patte 1966, Bauer et al. 1969, Gunn 1969, Harris and Kostuik 1970, Gagnaire et al. 1970, Artigou 1971, Appel and Friberg 1972). It would seem, therefore, that pain was due to mechanical factors.

Helal (1965) claimed to be able to analyse three different types of pain in patients

with gonarthrosis. The first type he called muscular which was described as a cramp-like pain felt in the muscles, above all the quadriceps, after and during exercise. Another type was called capsular and was said to be a sharp pain felt usually on the inner side of the back of the knee upon moving the joint. Helal claimed this kind of pain to be reproducible by forced extension or flexion of the knee. The third kind of pain was called venous and described as a diffuse dull aching pain around the knee usually worsening during the course of the day and persisting for a while in bed. This pain Helal could reproduce by artificially raising the intramedullar pressure of bone adjacent to an involved joint. Using intra-osseous phlebography he also showed pathologic intra-osseous vessels near involved joints in patients who suffered from the venous type of pain.

Arnoldi et al. (1972) have demonstrated that the intra-osseous pressure is elevated in the hip region in coxarthrosis in patients who have pain at rest, and that both the high pressure and the rest-pain may disappear after osteotomy. In their report of osteotomy in gonarthrosis Appel and Friberg (1972) found no correlation between the improvement of pain at rest and correcting the deformity.

6. Biomechanics

Normally the angle between the axes of the femoral and tibial shafts (FT) is 174° . This so-called physiologic valgus position is $172-176^{\circ}$ in 58 % and $170-178^{\circ}$ in 87 % (Mikulicz 1878, Fick 1916).

The biomechanics of the knee have been analysed by many workers. The following summary is based mainly on Bouillett and Van Gaver (1961), de Marchin et al. (1963b) and Maquet et al. (1967 a and b):

The forces around the knee at the moment of weight-bearing can be best demonstrated in the situation of standing on one leg (Fig 1). The compression force of gravity (F) is, thus, falling medial to the knee. This force is balanced by the traction in the lateral stabilizing structures, i.e. the collateral ligaments, the fascia lata and tractus ilio-tibialis. This counter-force is called C. At equilibrium the two forces, each multiplied by its lever arm, must be equal; in a normal knee the resultant force (R) will fall through the middle of the knee and coincide with the mechanical axis. The condyles are then symmetrically loaded.

In the abnormal situation of varus position (Fig 1 c) F has moved medially. Its lever arm is, thus, longer causing the resultant R to increase and to move medially away from the middle of the joint; the medial articulation is over-loaded.

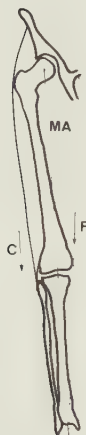


Fig 1 a

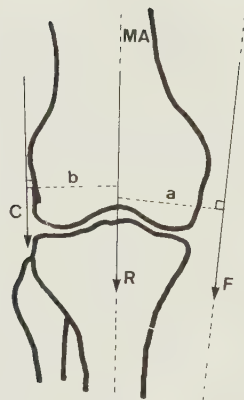


Fig 1 b

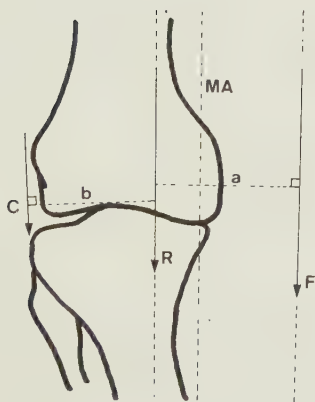


Fig 1 c

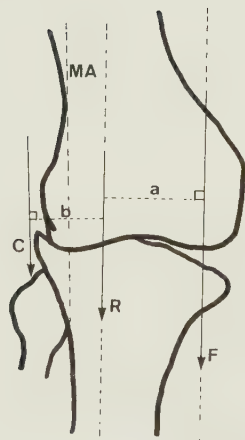


Fig 1 d

Fig 1. BIOMECHANICS OF THE KNEE.

a and b) normal knee, c) varus deformity, d) valgus deformity

In the abnormal situation of valgus position (Fig 1 d) F has moved laterally toward the center of the knee. Its lever arm is, thus, shorter to cause the resultant R to decrease and to move laterally. In milder forms of valgus deviation the displacement of R is compensated by decreased force as a consequence of diminishing the lever arm a. This is probably the explanation for the clinical symptomatology of valgus deformity causing less pain than varus deformity. With larger deformities, however, the displacement of R cannot be compensated for, and the lateral articulation will be overloaded.

This theoretical discussion has been substantiated by photoelastic studies of models based on radiograms of the knee (Maquet et al. 1966). Maquet and his co-worker have calculated the above mentioned resultant in a normal knee of a man weighing 60 kg to be around 128 kg. This load is then evenly distributed at the femoro-tibial articulation. A 10° varus deformity may double the load on the medial femoro-tibial articulation.

The load in a normal knee works perpendicular to the articular surface. This is not true if there is a marked inclination of the joint line, for example as an effect of osteotomy in a case of valgus deformity. It has, however, been shown by photoelastic studies (Maquet et al. 1966) that the load is evenly distributed over the articular surface as long as the obliquity does not exceed 10° .

B. EARLIER WORK ON OSTEOTOMY FOR GONARTHROSIS

1. Indications for osteotomy

The generally accepted indication for osteotomy in gonarthrosis is varus or valgus deformity. Most authors agree that the process should involve only one of the two femoro-tibial articulations, but there is no unanimous opinion regarding what degree of arthrosis constitutes an indication for the operation. Bouillet and Van Gaver (1961) did an osteotomy only when the mechanical axes were displaced from the center of the knee more than 2 cm in valgus cases and more than 1 cm in varus cases. They also stated, however, that it is too late to do the operation when obliteration has developed. This would leave few cases suitable for osteotomy. Wiley (1967) described the osteotomy as suitable for gonarthrosis when "surgery is indicated but arthrosis is considered to be too drastic".

Moderate restriction of the range of motion of the knee is generally not held to preclude osteotomy. Jackson (1969) claimed, however, that an extension defect of

more than 20° contraindicates osteotomy. Likewise, most authors feel that flexion should be at least 90° .

Gross instability was regarded as a contraindication by Jackson et al. (1969) but Gagnaire et al. (1970) felt that ligamentous instability is a sign of incompensation which strengthens the indications for osteotomy. However, subluxation in any plane is a contraindication to osteotomy according to Debeyre and Patte (1966). Coventry (1973) stated that the patients must be able to use crutches after operation, do simple exercises and that hip, foot and ankle function should be adequate enough so as not to hinder rehabilitation. Serious arterial deficiency is a contraindication to surgery. High age and obesity are generally not held to be contraindications.

2. Radiographic techniques and estimating the desired correction

The importance of radiograms obtained in standing position for assessing the two femoro-tibial articulations was pointed out by de Sèze and Coliez (1949), de Marchin et al. (1963 a and b) and thoroughly demonstrated by Ahlbäck (1968). This technique has now become standard examination in gonarthrosis. In osteotomy cases, this technique is used preoperatively for calculating the desired correction (Ramadier and D'Aubigné 1965, Wiley 1967, Devas 1969, Bauer et al. 1969, Harris and Kostuik 1970, Gagnaire et al. 1970, Coventry 1973, Shoji and Insall 1973). Of recent authors only Artigou (1971) did not use roentgenograms taken in the standing position for estimating the articular space and the desired correction. He calculated the anatomical axes on standard radiograms in frontal projections.

3. Operative techniques and postoperative programs

Jackson and Waugh (1961) originally described a ball and socket type tibial osteotomy just distal to the tibial tuberosity. After correction the leg was immobilized in a long plaster cast for 8-10 weeks with weight-bearing allowed after 4-6 weeks. A similar technique was used by Wardle (1962) who used a groin-to-foot plaster until radiographic union, and then a below the knee plaster for four weeks. Venemans (1962) fixed his osteotomies with skeletal pins, and started knee movements within a few days, but applied a walking plaster at eight weeks. A similar technique was used by Goerttler and Debrunner (1969) and Gunn (1969). Bouillet and Van Gaver (1961) had already described the advantage of using a high osteotomy, i.e. an osteotomy through the tibial metaphysis immediately above the insertion of the patellar tendon at the tibial tuberosity. This provides correction near the place of the deformity, and is performed in cancellous bone with optimal conditions for healing. The osteotomy is stabilized by the tension in the quadriceps muscle. This method permits early

weight-bearing. The high osteotomy has been widely used with or without internal fixation (Coventry 1965, Ramadier 1967, Debeyre and Patte 1966, Maquet et al. 1967, Herbert et al. 1967, Bauer et al. 1969, Harris and Kostuik 1970, Artigou 1971, Appel and Friberg 1972, Shoji and Insall 1973, Coventry 1973). Gariépy (1964) used external compression devices. The place and the method of osteotomizing the fibula differ somewhat. The possibility of tightening the collateral ligaments in the same operation has been elucidated by Ramadier (1967) and Coventry (1965 and 1973).

4. Results of osteotomy

The first published results of osteotomies were rather small, and, therefore, not suitable for extensive analysis. Ramadier et al. (1965) were the first to publish material extensive enough for analysis. They had good results in 55 of 65 cases; there was a clear correlation to correction of the deformity. Furthermore, the results seemed to be better in secondary arthrosis. Jackson et al. (1969) analysed their cases of 70 osteotomies, and found complete relief of pain in 50 cases with an additional 17 considerably improved. The preoperative degree of deformity did not appear to influence the results.

Bauer et al. (1969) were the first to present their results in terms of clearly defined criteria. Their 66 operated knees were evaluated in terms of mobility, stability and freedom from pain. Before operation none were pain-free, stable and mobile, while postoperatively 37 fulfilled these criteria. Preoperatively 19 knees were immobile, unstable and painful, while only four had the same classification afterwards. There was also a clear correlation between good correction and good results. This correlation has later been confirmed by others (Gunn 1969, Harris and Kostuik 1969, Gagnaire et al. 1970, Artigou 1971).

Appel and Friberg (1972) distinguished between pain at rest and pain on walking. They did not find any correlation between good results in regards to pain at rest and good correction of deformity.

Artigou (1971) has analysed the results of 260 high tibial osteotomies. He found good results and satisfied patients in 77 % of the cases. The walking ability was improved in 60 %. He found the results were inferior in knees with preoperative laxity while co-existing patello-femoral arthrosis was of no significance. If a good position in the knee was obtained there was no difference between medial or lateral arthrosis. He also found that posttraumatic cases had the most favourable outcome.

Shoji and Insall (1973) have analysed 49 osteotomies performed for valgus deformity in the same terms as Bauer et al. (1969). They found significantly inferior results in this group as compared to varus cases, and concluded that this difference is due to the inclination of the joint line which follows tibial osteotomy in valgus but not in varus cases.

Coventry (1973) has published his data on 71 patients with tibial osteotomy for arthrosis in 86 knees. He had very good results in 76 knees and fair in seven. Only three did poorly.

II. METHODS AND MATERIAL

At the orthopaedic department in Lund, Sweden high tibial osteotomy was introduced late in 1969 as a standard procedure for gonarthrosis with involvement of one of the femoro-tibial articulations. This investigation deals with all cases operated upon from that time to the end of 1971. A follow-up study was performed in 1972-1973.

The indications for operation were pain and ambulation difficulties in patients who had not been helped by conservative methods. The indications were rather lenient: late age, obesity or mild heart incompensation were not regarded as contraindications. One patient (no 5) suffered from renal failure.

A. METHODS

In each case records were kept on clinical and radiographic observations, type of operation, hospitalization and immobilization times, complications and other pertinent data. In bilaterally operated cases, one record was kept for each knee. All data were coded and stored on tape in a PDP-8 E minicomputer. The computer was programmed to allow the user direct access to all data displayed in any subset of combinations fulfilling criteria specified by the user. These manoeuvres were handled by the author. The data used in the following analysis are recorded in an Appendix that has been deposited with the Lund University Library and also is available on request from the author or the office of the Department of Orthopaedic in Lund.

1. Clinical examination

Preoperatively each patient was questioned and examined according to a predetermined protocol. The same protocol was used at the follow-up study, but was then enlarged to record the patients' opinions of the result of the operation, their ability to engage in daily living activities, and an analysis of their postoperative mobility in terms of ambulation pattern, ability to run, jump and mount steps.

Joint motion. For the purpose of this study the knee joint was assumed to be a true hinge joint. Zero starting position was defined as the extended straight knee. Flexion was measured in degrees from the zero starting point. A knee with an extension defect of 10° and flexion of 90° was said to have an extension of -10 with flexion to 90° or flexion $10-90^{\circ}$. A knee with hyperextension of 10° was said to have an extension of $+10^{\circ}$. Unless stated otherwise, values for motion shown here mean active mobility.

Stability or instability were defined as absence or presence, respectively, of appreciable medial or lateral thrust (Bauer et al. 1969) of the knee joint at the moment of weight-bearing (Fig 2).

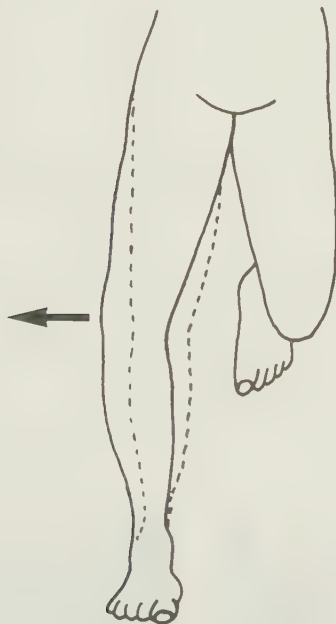


Fig 2. Lateral thrust

Laxity was defined as the possibility of manually provoking an abnormal deviation in the frontal plane in a sub-maximally extended knee. A prerequisite condition for this phenomenon is either insufficient ligamentous stability or major bone loss.

2. Radiographic examination

The radiographic appearance of gonarthrosis was thoroughly described by Ahlbäck (1968). His terminology has been adopted here as follows.

Articular space: The distance on the radiograms between adjacent articular bone surfaces. The femoro-tibial articular space was said to be narrowed when it was less than half the width of the articular space in the other articulation of the same knee or the same articulation of the other knee, or when it was less than 3 mm in width.

Obliteration: Was said to exist when two adjacent articular bone surfaces were in contact. - Sclerosis: Cancellous bone with increased density. - Attrition: Loss of bone in a weight-bearing condyle. Ahlbäck described three grades of attrition, 1) defects of less than 5 mm, 2) defects of 5-10 mm, and 3) defects of more than 10 mm. This classification was simplified in the present study to two groups - defects greater or lesser than 7 mm.

Articular subluxation was defined here as translation in the frontal plane of the tibia on the femur of more than 5 mm.

Standard frontal and lateral projections and an axial projection of the patella were obtained in each case.

In 1967 Norman modified Ahlbäck's (1968) method for roentgen examination in standing position, obtaining frontal projections with provoked varus and valgus position (Fig 3). This method was used preoperatively. Postoperatively a projection obtained in the standing position without provocation was included. Examinations in the standing position was done with an film-focus distance of 150 cm.



Fig 3 a



Fig 3 b

Fig 3. Provoked varus(a) and valgus(b)

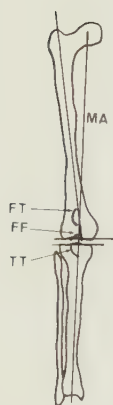


Fig 4 a

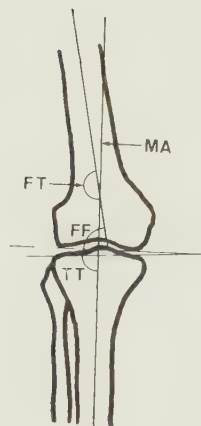


Fig 4 b

Fig 4. Angles in the frontal plane

The radiograms were used for measurement of the following angles (Figs 4 and 5). The femoro-tibial angle (FT) was defined as the angle between the axes of the femoral and tibial shafts. It was measured from radiograms obtained with the patient standing either in provoked varus or valgus (FTP) or without provocation (FTS).

FF was the angle between the axis of the femoral shaft and the tangent to the condyles of the femur. TT was the angle between the axis of the tibial shaft and the tangent to the articular surfaces of the tibial condyles. - TTS was the angle in the sagittal plane between the axis of the shaft of the tibia and the tangent to the articular surface of the tibial condyles (Fig 5).

The mechanical weight-bearing axis (MA) of the leg was defined by a line from the center of the femoral head to the middle of the tibio-talar joint (Fig 4 a).

The angles defined above are in reality phenomena in three dimensions. Relevant errors in measuring of these angles may occur (1) because the radiographs were not obtained in the exact frontal or lateral projections, and (2) because of inaccurate recognition of essential landmarks in the radiographs.



Fig 5. Angle in the sagittal plane

Ad (1). According to spatial geometry (Norman 1973), the angles discussed here are rather insensitive to rotational inaccuracy of less than 25° (Fig 6). Rotational inaccuracy very probably never even approached this value during the period of investigation. Thus, each of the 77 examinations, which included more than one frontal or lateral projection, was checked for variations in the values of angles FF and TT, respectively. The mean value of this variation was 1.3° with a standard deviation of 1.3° . The maximum difference was 6° in one case and 5° in another case.

Ad (2). The tangents to the femoral and tibial condyles and the axes of the distal third of the femoral and proximal third of the tibial shafts were identified on the radiograms. The angles were then obtained from these lines with a protractor. Measurements on the same radiogram on different occasions by the same examiner differed at most 4° and in most cases less than 3° . In 15 knees two independent examiners differed by 4° in two cases, by 3° in two cases and in the rest less than 3° .

3. Operative technique

Preoperatively at an out-patient visit, the patients were informed both verbally and by a specially printed pamphlet about the nature of the disease, about the operation, and about the importance of exercising the quadriceps muscle.

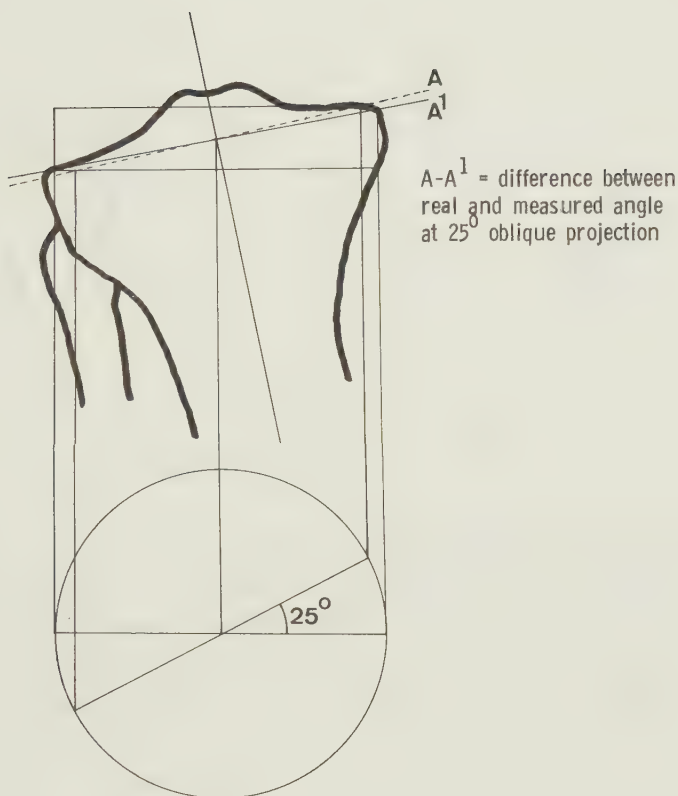


Fig 6. Effect of rotational inaccuracy on measurement of angles in the frontal plane

The operation was performed under epidural or general anaesthesia with a femoral tourniquet. A pillow was placed under the distal thigh and the knee was thus slightly flexed to minimize pressure on the structures in the popliteal space. After the joint line had been identified, a transverse incision was made along half the circumference of the leg at the level of the tibial tubercle. In varus deformity the lateral part of the tibial metaphysis was dissected subperiosteally to the back of the tibia. On the medial side a small incision was made through the pes anserinus and the periosteum at the postero-medial corner of the tibia. Retractors were then introduced laterally and medially to the back of the tibia to protect the popliteal structures, and the patellar ligament was dissected a few millimeters distal to the tibial tubercle to obtain a larger field for the osteotomy. A closed wedge osteotomy was then made just



Fig 7. Osteotomy for varus deformity

proximal to the tibial tubercle with a chisel or oscillating saw. The height of the base of the wedge was calculated from the radiograms; 1° of a malalignment roughly corresponds to 1 mm of height at the base (Bouillet and Van Gaver 1961). In varus cases the fibula was handled in one of two ways. At the outset of this series, the tibio-fibular articulation was sharply divided and the head of the fibula was allowed to slide upwards (Bauer et al. 1969). This technique was later abandoned and in lieu a partial resection of the fibular head was performed (Coventry 1965). (Fig 7). After the osteotomy had been closed, internal fixation with a staple was often employed. Finally, the fascia and muscles were carefully sutured. A suction drainage was always used, and the knee was immobilized in plaster from the groin to the ankle with the knee in straight position.

4. Postoperative regimen

Postoperatively, the patients were encouraged to exercise vigorously by moving all free joints and by isometric contraction of the muscles in the plaster concentrating on the quadriceps muscle. At least partial weight-bearing was allowed the day after the operation. The patients left the hospital as soon as they were able to manage themselves, and in many cases before the end of the second postoperative week. The mean hospitalization time was 18 days. (Fig 8). In this figure all days in the hospital post-surgery on either knee were counted. Thus, if reoperations or mobilization under anaesthesia were performed, these hospital days were added to the total hospitalization period.

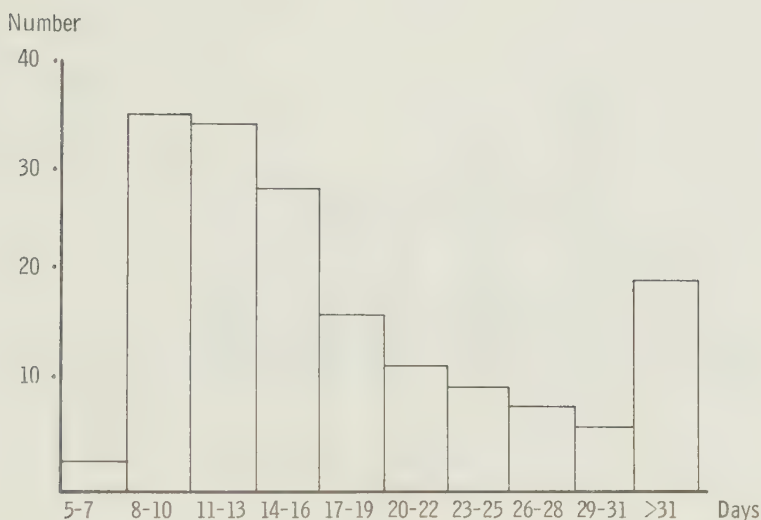


Fig 8. Periods of hospitalization for osteotomy

The knee was immobilized in the plaster cast for 6-8 weeks with weight-bearing allowed or even encouraged. After the cast had been removed, the patients were usually able to regain knee flexion without the aid of physiotherapists. Some cases, however, were referred to physiotherapists for knee flexion and extension exercises, and manipulation under anaesthesia was done if flexion to 90° was not regained within a months or two.

B. ORIGINAL MATERIAL (Fig 9)

The original material consisted of 118 women and 44 men with a mean age of 65 years (Fig 10). The youngest patient was 44 and the oldest 82 years.

1. Radiographic classification

Type of gonarthrosis was classified according to Ahlbäck (1968) with the aid of a Venn-diagram (Fig 11). The pure medial type (M) were in majority (120 of 176 knees). 13 were lateral (L), 30 were medial-patellar (MP), and 12 were lateral-patellar (LP), respectively. One knee had degenerative changes in both femoro-tibial compartments secondary to trauma.

The distribution of the material among different types of gonarthrosis was rather similar to Ahlbäck's (1968) unselected series except that pure femoro-patellar arthrosis was not included here; this condition is not treated by high tibial osteotomy.

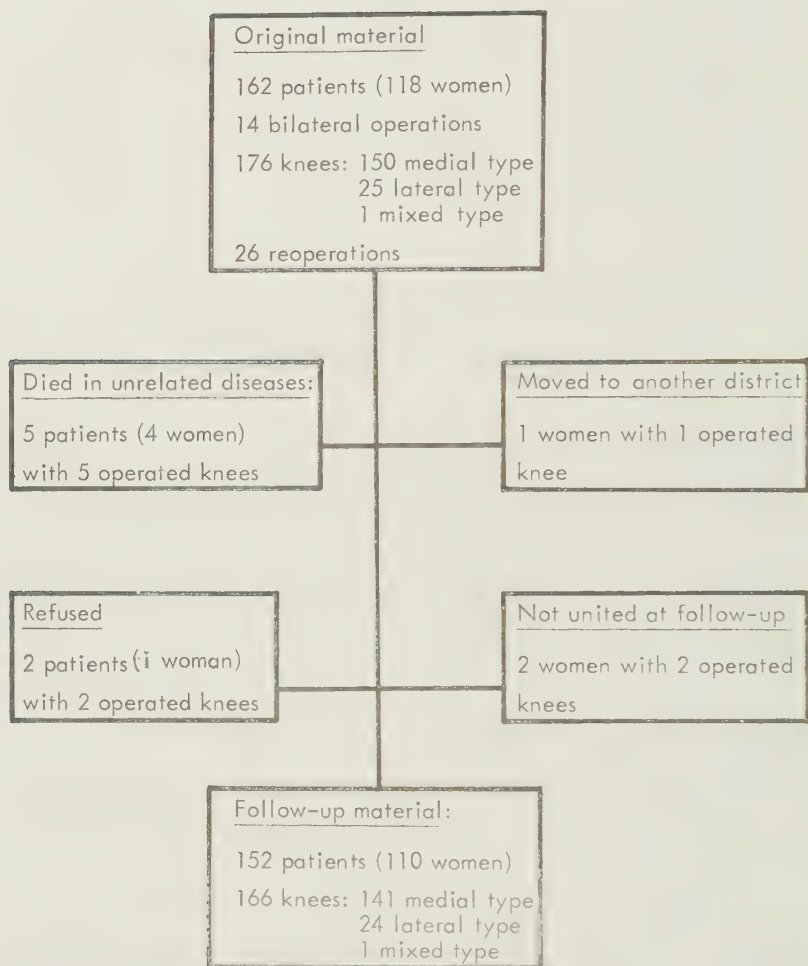


Fig 9. The material

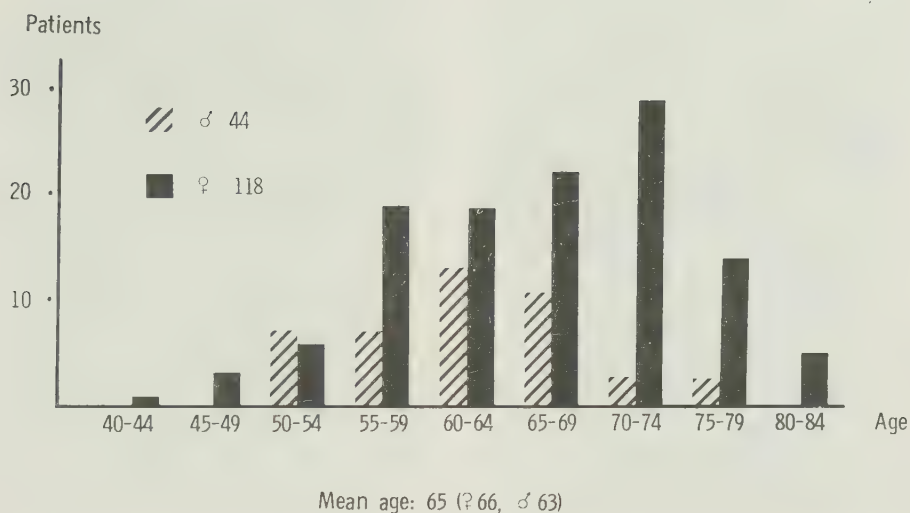


Fig 10. Age distribution

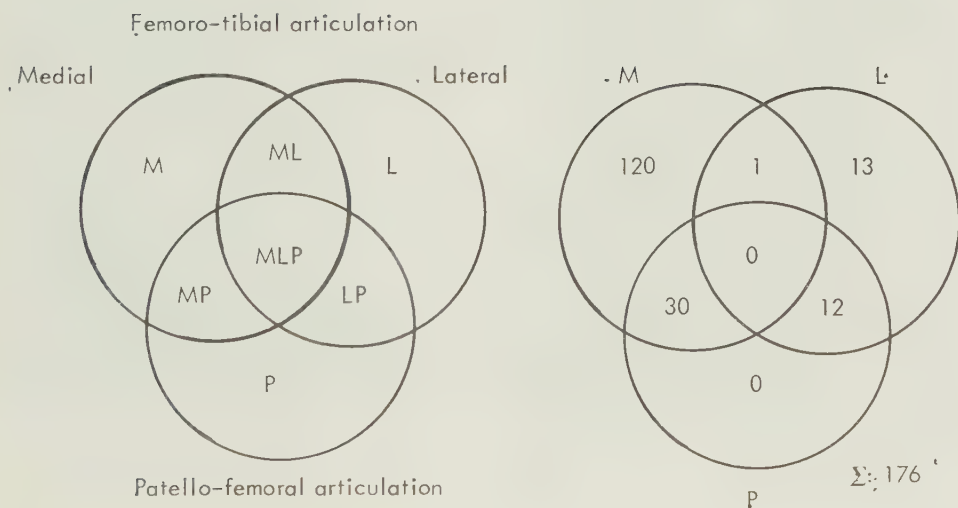


Fig 11. Classification diagram for gonarthrosis with number of cases in each subset.



Fig 12. Knee no 109. Medial type of arthrosis grade I. Narrowing of medial articular space in standing position with varus provocation. Chondrocalcinosis.



Fig 13 a. Knee no 16. Medial type grade II. Obliteration of articular space. Four months postoperatively with delayed union and recurrence of deformity.

Degree of arthrosis. Ahlbäck has described the gradual development of femoro-tibial arthrosis from destruction of cartilage to attrition of bone with subluxation as the final stage. Based on this concept five different grades of radiographic severity were distinguished here.

Grade I: Narrowing of the articular space, 11 knees (Fig 12)

Grade II: Obliteration of the articular space, 55 knees (Fig 13)

Grade III: Moderate attrition of bone with the defect smaller than 7 mm, 82 knees (Fig 14)

Grade IV: Severe attrition of bone with the defect larger than 7 mm, 14 knees (Fig 15)

Grade V: Subluxation, 14 knees (Fig 16)



Fig 13 b. Knee no 16. After reoperation healed in good position.

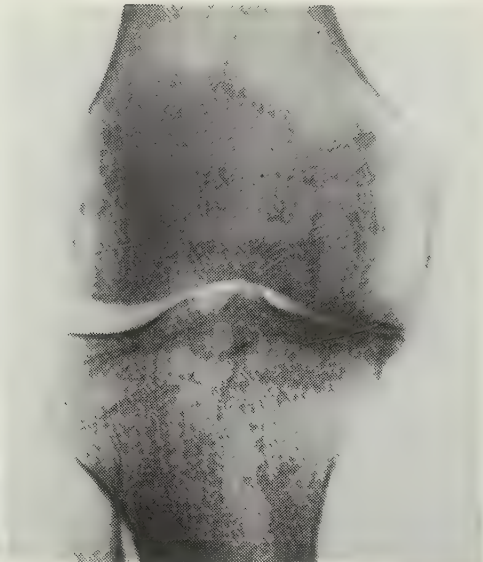


Fig 14 a. Knee no 188. Medial type grade III. Preoperative standing provoked projection.

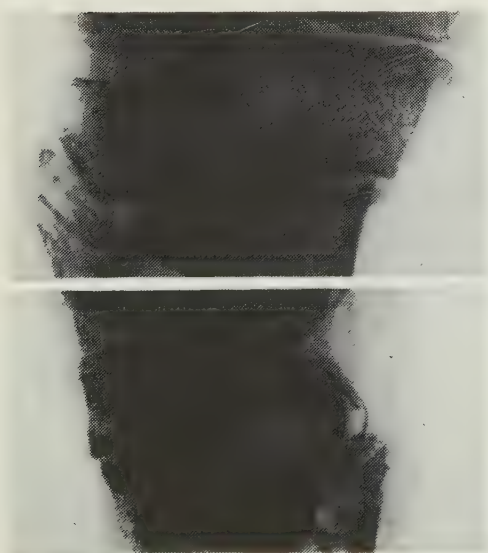


Fig 14 b and c. Knee no 188. Two months after osteotomy resorption and sclerosis around osteotomy



Fig 14 d. Knee no 188. Five months after osteotomy. Healed in good position.



Fig 15 a. Knee no 10. Lateral type grade IV. Preoperative standing provoked projection. Note gaping at medial femoro-tibial articulation.



Fig 15 b. Knee no 10. After osteotomy the joint line is inclined and weight-bearing seems to hit the tibial spine.



Fig 16 a. Knee no 71. Medial type grade V. Preoperative standing provoked projection. Note that the lateral subluxation of the tibia is partly disguised by large osteophyte which has formed on the medial tibial condyle.



Fig 16 b. Knee no 71. Postoperatively pronounced forward angulation in the osteotomy.

Severe arthrosis predominated; 110 of 176 had developed attrition of bone. In general the degree of arthrosis worsened with age (Table 1).

Table 1. Age Distribution in Different Degrees of Arthrosis.

Age	Number of knees in each grade				
	I	II	III	IV	V
75	0	5	9	6	3
70-74	0	6	20	4	5
65-69	2	7	23	0	4
60-64	2	22	10	1	0
55-59	4	7	16	2	1
55	3	8	4	1	1
Mean age	58	62	66	70	68

Also, the deviation from the physiologic valgus position (Table 2) was more pronounced in more severe grades of medial type of arthrosis. The correlation of degree of arthrosis with age and deformity confirm the validity of the radiographic classification.

Table 2. Mean Deviation from 174° of the FTP-Angle in Different Degrees of Medial Type of Arthrosis.

Grade	Mean Deviation
I	$8,3^{\circ}$
II	$10,6^{\circ}$
III	$11,4^{\circ}$
IV	$15,9^{\circ}$
V	$15,6^{\circ}$

2. Etiology of gonarthrosis

Regarding etiologic factors the patients were classified on the basis of case history, clinical and radiographic examinations. 125 patients had arthrosis of the idiopathic type in 139 knee joints. 35 patients had secondary arthrosis while two knees had atypical arthrosis (Table 3).

Table 3. Etiology of Gonarthrosis in 162 Patients Operated with Osteotomy.

Etiology	Patients	Knees
Idiopathic	114	128
Idiopathic with pyrophosphate synovitis	11	11
Posttraumatic	19	19
Arthrosis after arthritis	1	1
Arthrosis after spontaneous osteonecrosis	5	5
Arthrosis associated with hip disease	10	10
Not classifiable	2	2

a. Idiopathic (primary) arthrosis

Two thirds of the knees had idiopathic gonarthrosis, and most patients claimed to have had straight legs in their youth. The mean age in this group was 64 years with a ratio women/men of 2.7, i.e. in almost exact agreement with Ahlbäck (1968). In this group 95 were of the medial type, 22 medio-patellar, 6 lateral and 5 latero-patellar. All bilaterally operated patients belonged to this group.

Pyrophosphate synovitis (pseudogout) has been diagnosed with rising frequency in recent years. In the knee joint it manifests itself either as an acute arthritis or, more commonly among women as a more chronic disease (Bjelle and Sundén 1971) characterized by recurrent synovitis. In many cases it co-exists with gonarthrosis. Whether pyrophosphate synovitis is a disease *sui generis* or an unspecified pattern of reaction, is open to discussion (McCarty 1966). At any rate, cases of pyrophosphate synovitis were analysed separately in this study. The diagnostic criteria were identified by polarized light microscopy of calciumdihydropyrophosphate crystals, and by radiography of calcifications in menisci or articular cartilage (chondrocalcinosis, Fig 12). Pyrophosphate synovitis was found in 11 knee joints in 9 women and 2 men with a mean age of 67 years. This sex distribution is quite different from Bjelle and Sundén's (1971) material which consisted of 10 men and 5 women. This possibly reflects another manifestation of the sex difference in symptomatology described by Bjelle and Sundén (1971). Six knees belonged to type M, one MP, two L and two LP. Signs of hyperparathyroidism, diabetes mellitus, gout or rheumatoid arthritis were not observed.

b. Posttraumatic arthrosis

Unilateral arthrosis was classified as posttraumatic when earlier records and/or radiograms revealed intraarticular fracture, a fracture of the shaft of the femur, or if a healed tibial lesion was demonstrated with deformity in the frontal plane. Posttraumatic arthrosis was also diagnosed in unilateral cases when records gave evidence for trauma with haemarthrosis and clinical examination revealed persisting laxity or a positive draw sign or other evidence for severe ligamentous injury. Posttraumatic arthrosis was diagnosed in 8 women and 11 men with a mean age of 57 years. Twelve knees were categorized in type M, one MP, one ML, two L and three LP.

Table 4. Type of Injury in 19 Cases of Posttraumatic Femoro-Tibial Arthrosis.

Fracture of the shaft of tibia with residual deformity	8
Fracture of the shaft of femur with residual deformity	2
Fracture of tibial condyle	5
Fracture of the shaft of tibia and tibial condyle	1
Ligamentous injury with residual laxity	3

c. Arthrosis secondary to arthritis

Arthritis of the knee usually causes arthrosis of both femoro-tibial articulations of a type which does not lead itself to tibial osteotomy. Here only one case fell in this group - a woman with disseminated lupus erythematosus which had caused medio-patellar type arthrosis of degree II.

d. Osteonecrosis of the knee

Osteonecrosis of the knee has been described by Ahlbäck et al. (1968). The condition usually starts with sudden onset of severe knee pain. The radiogram is normal for at least two months, but later a typical radiolucent lesion develops in the medial femoral condyle. The condition which usually affects women over 65, heals spontaneously, but in most cases a typical medial arthrosis develops. The diagnosis in these cases was established by the typical radiographic appearance (Fig. 17). All patients were women with a mean age of 72. The arthrosis was always of the medial type.

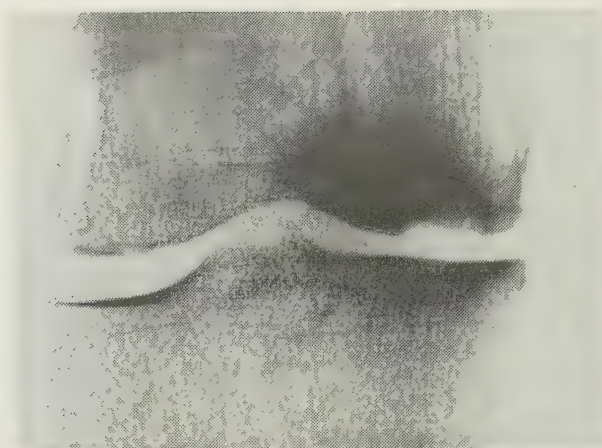


Fig 17. Knee no 57. Osteonecrosis with typical lesion at the medial femoral condyle. Non-weight-bearing projection.

e. Gonarthrosis associated with hip disease

Foss Hauge (1973) has analysed knee problems after arthrodesis of the hip. He notes that hip disease with restricted motion causes unphysiologic strain on the knee. Accordingly, it is clear that some cases of gonarthrosis are secondary to hip disease, for example high dislocation of the hip with adduction contracture or in cases of ankylosis or arthrodesis with leg shortening or inappropriate position in the hip joint. In other cases this etiologic connection may be less clear in which case they are classified separately (Table 5).

Table 5. Type of Hip Problem in 10 Patients with Associated Femoro-Tibial Arthrosis.

Hip problem	Type of arthrosis
Arthrodesis after tuberculous coxitis	M
Ankylosis and leg shortening after tuberculous coxitis	MP
Bilateral congenital dislocation of the hip with adduction contracture	L
Congenital dislocation of the hip with adduction contracture	LP
Contralateral congenital dislocation of the hip with adduction contracture	M
Coxarthrosis, operated with Charnley arthroplasty	L
Coxarthrosis operated with Charnley arthroplasty	MP
Contralateral coxarthrosis operated with Charnley arthroplasty	M
Bilateral coxarthrosis with slight restriction of mobility	MP
Ipsilateral coxarthrosis after epiphysiolysis, operated with Charnley arthroplasty	L

C. FOLLOW-UP MATERIAL (Fig 9)

During the period of observation five patients have died secondary to unrelated diseases – three malignant tumours, one cardiac infarct and one allergic pancytopenia. One patient had moved to another district and been treated for her knee disease. Two patients have refused to submit to follow-up examination. As can be judged by the case records the course was favourable in all except two cases. One patient (no 168) died of pancytopenia complicating a grave asthmatic bronchitis before a reosteotomy had united. The other patient (no 28) had moved to another district and was reoperated on twice, with an eventual arthrodesis. Eight patients with a mean age of 71 years were thus lost to follow-up – six women and two men. The type of arthrosis was medial in seven and lateral in one. The severity of the arthrosis was grade I in one case, grade III in four, grade IV in one and grade V in one. In five cases the arthrosis was considered idiopathic of which one had pyrophosphate synovitis. Two cases were secondary to fracture and one secondary to hip disease.

Patients lost to follow-up thus differed from the total only in mean age; death was the common cause of drop-out. The follow-up material was, therefore, regarded representative of the total material consisting of 154 patients. In two of those (nos 153 and 170) the osteotomy had not united at the time of follow-up. This left 152 patients for final analysis, 110 women and 42 men, with 166 knees (141 medial, 24 lateral and one medio-lateral type arthrosis).

1. Follow-up procedure

The patients were called for follow-up examination by the author during 1972–1973. They were questioned and examined according to a predetermined protocol which was an enlarged version of the one used preoperatively. The patients were also asked for their opinion about the result of the operation regarding pain at rest, pain on walking and walking ability, Activities of daily living before and after operation were explored. Signs and symptoms from the lower leg that could be attributed to post-thrombotic phenomena or inappropriate load on the foot and ankle joint were sought. The examination included assessment of the hip and ankle joints, vascular or neurologic tests, and a test of the patients' ability to walk, run, jump and to sit up from and mount stools of different heights.

The radiographic examination was performed as was the preoperative exam except that the standing projections did not include provocation. The follow-up examination occurred at least one year following the last operation. The mean observation time was 18 months. In 85 cases it was 12–18 months, in 54 cases 18–24 and in 26 cases more than 24 months.

2. Assessment of results

The results of a high tibial osteotomy were assessed regarding, (1) correction of deformity and (2) effect on symptoms.

a. Correction of deformity

The anatomical femoro-tibial angle is normally 174° with a range of $170-178^{\circ}$, and the mechanical axis thus falls through the center of the knee. Maquet et al. (1967 a and b) have recommended correction of a valgus deformity to a neutral position and a varus deformity to $3-5^{\circ}$ of over-correction. Bauer and co-workers (1969) aimed at an anatomical tibio-femoral angle of between 174 and 177° based on the observation that all knees in their material were outside these limits preoperatively. Harris and Kostuik (1970) attempted to reconstruct the mechanical axis to fall through the center of the knee. Kettelkamp and Chao (1972) have done a very elaborate analysis of the medial and lateral compressive forces in the knee during standing using planar analysis with a computer. On six foot standing bilateral roentgenograms they made extensive measurements of different parameters of the knee joint. Nothing was said, however, about how they defined the frontal plane, and it is not certain that the radiographic technique permits such a high degree of accuracy. However, they concluded that if one selects a position of equal compressive forces by unit area as a neutral position, a varus deformity could be over-corrected $3,5-4^{\circ}$ and a valgus deformity over-corrected $1,5-2^{\circ}$ measured as the mechanical femoro-tibial axis. The difference between the mechanical and anatomical axes of the femur is 6° (Fick 1916). Translated to mechanical femoro-tibial angles, Kettelkamp and Chao's recommendation would then be to correct a valgus deformity to $174-178^{\circ}$ and a varus deformity to $170-172^{\circ}$. In practical work such precision is at present impossible. The measurements used here had an inaccuracy of about 2° . A femoro-tibial angle of $168-180^{\circ}$ in standing position without provocation was, therefore, considered normal.

b. Effect on symptoms

It is the pain that forces the patient with gonarthrosis to the doctor, and in nearly all cases this symptom is the main indication for an operation. Pain is a subjective phenomenon, and as such not directly measurable. One, therefore, has to rely on the patient's statement in appraising the results of the operation. This is a source of inaccuracy. Some patients certainly do not want to disappoint their doctor, and, thus, express less pain than is evident. Most probably tell the truth. Realizing a general tendency to forget past rather than present problems, one could, perhaps, expect a trend of denying a positive effect of treatment.

Two kinds of pain were distinguished – pain at rest and pain at weight-bearing. The severity of pain was estimated in terms of consumption of analgesics. The walking ability was expressed as maximum walking capacity and the pain-free walking distance.

The pain-free walking distance was classified as follows:

- 1/ Pain from the first step
- 2/ Pain after walking less than 100 m
- 3/ Pain after walking 100–500 m
- 4/ Pain after walking 500–1000 m
- 5/ Pain after walking more than 1000 m
- 6/ Only pain at the start
- 7/ No walking pain

The maximum walking capacity was classified as follows without regard to the use of support:

- 1/ Capable of walking indoors only
- 2/ Maximum walking capacity less than 100 m
- 3/ Maximum walking capacity 100–500 m
- 4/ Maximum walking capacity 500–1000 m
- 5/ Maximum walking capacity more than 1000 m

Pre- and postoperative data on the above parameters were compared (Tables 10 and 11) by multiplying the number of knees with improvement in terms of classes and dividing this sum with the total number of knees in each group – an index of improvement was obtained. In this calculation each improvement from one class to another was given equal value. Because of this approximation the index was regarded as a rather rough estimate of improvement. It has not been subjected to statistical analysis.

A comparison was done between pre- and postoperative knee function expressed in terms of mobility, stability and freedom from pain (Bauer et al. 1969). By definition a mobile knee had at least 90° of flexion and at most 5° lack of extension. A stable knee did not exhibit medial or lateral thrust at the moment of weight-bearing, and freedom from pain was said to exist when the patient did not use analgesics more than occasionally, or if the patient stated he could walk more than 1000 m without pain.

c. Statistical methods

For calculation of statistical significance the Fischer exact probability test and Chi-square test were used. Only significance on the 1 % level or better ($P \leq 0.01$) was accepted.

III. RESULTS

A. COMPLICATIONS

There were no deaths in connection with the operation. Counting superficial infection and small wound necrosis as insignificant complications a total number of 33 major complications were recorded (16 %).

1. Non-union

Non-union occurred in seven primary operations and one reoperation. At the time of follow-up seven of these had been reoperated on of which six had healed and the seventh apparently healing (no 156). Knee no 170 was reoperated on because of undercorrection following a low osteotomy and is developing a pseudarthrosis. Since a Charnley compression device has been used for reoperations, non-union has not occurred.

2. Infections

In six knees there were superficial infections with slight drainage which rapidly healed following debridement and a brief period of antibiotics. There were no cases of deep infection.

3. Wound necrosis

In three cases there was a small wound necrosis found when the plaster was removed. The necrosis healed on conservative treatment in all.

4. Thromboembolism

In this series were active exercises and early mobilization the only thromboprophylactic procedures. In five patients pulmonary embolism was diagnosed. The patients were put on anticoagulant therapy, and all had successful results. The embolism occurred in three cases after three weeks, in one case after ten weeks, and in one case after thirteen weeks! In another three patients deep venous thrombosis was suspected. Their symptoms rapidly subsided with anticoagulant treatment.

At follow-up the patients were questioned and examined with respect to signs and symptoms of post-thrombotic events. Only two of the patients, with previous diagnoses of pulmonary embolism showed such symptoms in the form of edema and pain in the lower leg on prolonged standing. Most probably there were many cases in this series

with subclinical venous thrombosis. The observation time was too brief to evaluate the development of post-thrombotic symptoms. The patients in this study were probably too old to have time to develop such chronic symptoms.

5. Peroneal palsy

Not less than 16 cases showed postoperative weakness of foot-or toe dorsi-flexion. Two cases (nos 102 and 183) had obvious weakness immediately after the operation, but in all other cases there was a time lag before the weakness appeared. In six cases the onset occurred during the first week and in eight after the first week. The peroneal nerve was not identified during the operation, but the long time lag before symptoms appeared strongly suggested that the nerve had not been injured during the operation. The probable cause in most cases was a combination of edema in the operative field and pressure from the plaster. Stretching of the nerve could also be a cause, especially in cases of late onset. All these cases had a primary varus deformity. However, in five of the eight cases with late onset there was either a pronounced forward angulation of the tibial condyle with hyperextension or a bayonet deformation or recurvation of the leg which anatomically imply stretching of the nerve, particularly when the head of the fibula was not resected. In one case progressing signs of nerve weakness were present more than three months after osteotomy. In this cases the head of the tibia had angulated forward with both a genu recurvatum and a bayonet deformity (Fig 18). The patient was reoperated upon four months after the osteotomy, and a clear deformity of the nerve at the level of the fibular head was found; the nerve was stretched when the leg was hyperextended. The fibular head was excised and the symptoms completely disappeared.

One of the patients with pronounced peroneal palsy died during the observation time (no 168), but of the other only four had persisting symptoms at follow-up. Thus, one had a slight weakness of dorsiflexion of the great toe, one a decreased sensory perception at the dorsum of the foot, and two had combinations of these symptoms. None of these symptoms had functional significance. In many of these cases the weakness was only slight. It is possible that some of these cases of weakness of dorsiflexion of the foot have been cases of tibialis anterior syndromes because of edema or injury to the anterior tibial artery.

6. Fracture

In one knee (no 18) intraarticular fracture of the tibial condyles occurred during the operation. The fracture healed but the patient had a poor position in the osteotomy with persisting deformity, and was not completely relieved of pain.



Fig 18. Knee no 63. Forward translation and angulation of the proximal fragment. In this case the fibula head had not been removed but allowed to slide upwards. Late peroneal palsy developed, successfully treated by removal of the fibular head.

B. MOBILITY (Figs 19 and 20)

In 31 knees there was impairment in the range of motion of 20° or more. There was, however, an over-all gain of 2° calculated as mean value of gain or loss. This is probably explained by the forward angulation that nearly always occurred in the osteotomy. The angle TTS between the tibial shaft and the tangent to the articular surface of the tibial condyles in the sagittal plane, thus, was $85 \pm 4^{\circ}$ preoperatively and $95 \pm 9^{\circ}$ postoperatively. A lag of active extension compared to passive extension was not observed in any knees.

1. Manipulation in anaesthesia (Table 6)

Manipulation was performed to gain flexion in 8 knees usually with success. Probably, there would have been even better results in retaining preoperative motion if more knees have been manipulated.

Table 6. Gain in Flexion by Manipulations in Anaesthesia.

Number of manipulations	Gain
2	0°
1	10°
2	30°
1	35°
1	60°
1	90°

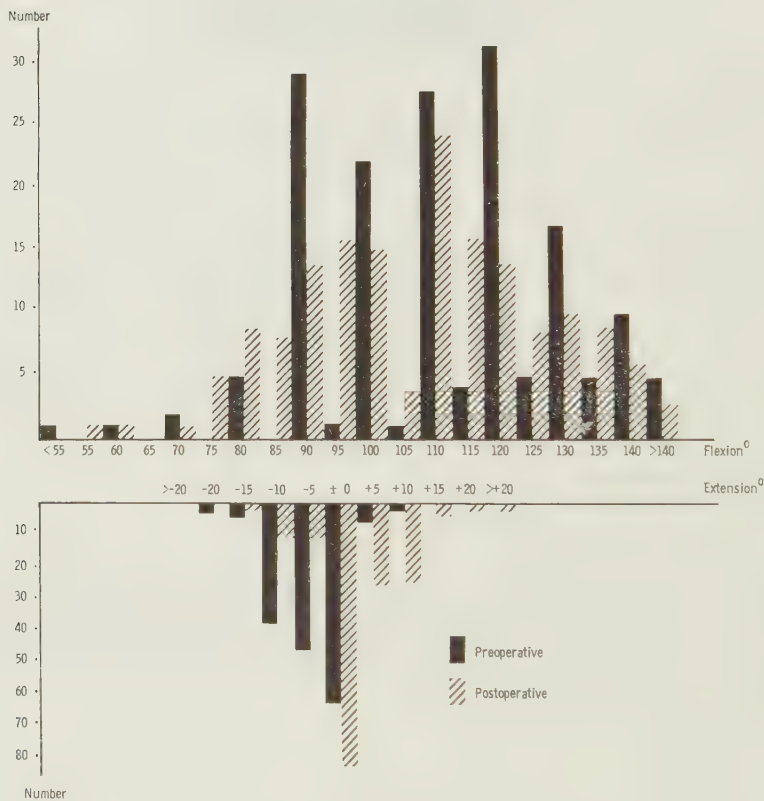


Fig 19. Pre- and postoperative flexion and extension

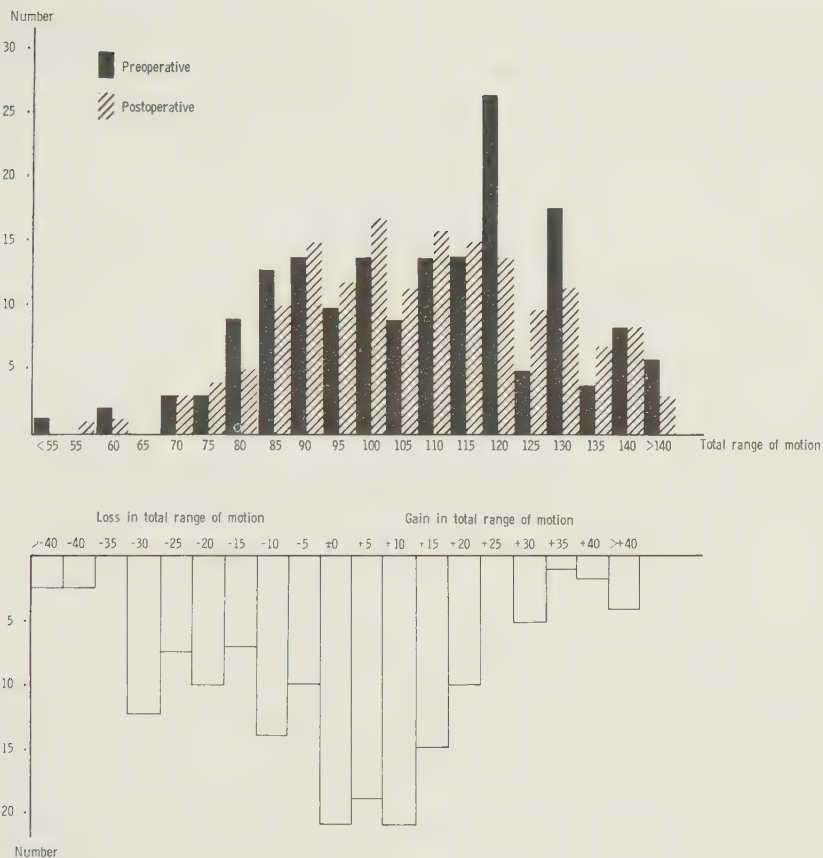


Fig 20. Pre- and postoperative total range of motion in degrees

C. CORRECTION OF DEFORMITY

The results of high tibial osteotomy were in 166 knee joints available at follow-up. 107 (65 %) had been adequately corrected using the definition that a normal FTS angle should be $168-180^{\circ}$. 59 knees, thus, still had malalignment. In medial arthrosis 94 were corrected and 47 uncorrected of which 31 were undercorrected and 16 overcorrected (Table 7). Of the 24 knees with lateral arthrosis 12 were corrected and 12 uncorrected all of which were overcorrected.

The chance of having adequate correction was equal in the five grades of arthrosis. The apparent difference in this respect between the two extremes, grades I and V, was not significant (Table 8).

Table 7. Correction of Deformity in Different Types of Arthrosis.

Type of femoro-tibial arthrosis	Corrected	Undercorrected	Overcorrected	Total
Medial	94	31	16	141
Lateral	12	-	12	24
Medio-lateral	1	-	-	1
Total	107	31	28	166

Table 8. Correction in Different Degrees of Arthrosis.

Grade	Corrected	Uncorrected	Total	Fraction corrected
I	9	2	11	.8
II	31	23	54	.6
III	53	22	75	.7
IV	9	4	13	.7
V	5	8	13	.4
Total	107	59	166	.7

17 knees were reoperated on because of residual deformity - 13 for under- and 4 for overcorrection. Of these, 12 were finally corrected and 5 remained uncorrected. Five knees were reoperated on because of pseudarthrosis; one resulted in good position and five had persisting malalignment. One knee was reoperated on because of recurvatum position which was successfully corrected. One knee was reoperated twice.

1. Time for loss of correction

In 53 of the 59 knees that were not corrected the radiograms permitted a decision as to whether the lack of correction was present immediately after the operation or occurred later. In 25 cases the immediate postoperative position was unacceptable. In three cases the correction was lost during the first week, in four cases during the first six weeks, i.e. in plaster, and in 21 knees after the sixth week.

2. Effect of operative technique on correction

During the time of investigation the operative technique was standardized and varied in only two respects. In some cases internal fixation with one or two Blount staples

was employed. However, the majority required no internal fixation. In some varus cases the fibular head was handled by sliding (Bauer et al. 1969), while in others the proximal part of the fibular head was removed (Coventry 1973). In some occasional cases an osteotomy of the fibular shaft was done. The correction with different operative techniques is seen in Table 9.

Table 9. Correction with Different Operative Techniques.

	Corrected Femoro- tibial angle	Fraction corrected	Total
<u>Internal fixation</u>			
with staple(-s)	39	.7	54
none	68	.6	112
<u>Fibular handling (only varus knees)</u>			
Sliding of the fibular head	34	.6	58
Resection of the fibular head	55	.8	73
Osteotomy of the fibular shaft	6	.5	11
<u>Combined</u>			
Sliding of fibular head without internal fixation	31	.6	54
Sliding of fibular head with fixation with staple(-s)	1	.2	4
Resection of fibular head without internal fixation	24	.8	31
Resection of fibular head with fixation with staple(-s)	31	.7	42

There was no relevant difference between the main groups in methods of fixation and only minimally better correction following resection as compared to sliding of the fibular head ($0.05 > P > 0.01$)

D. SYMPTOMS

1. Patients' opinion

Out of the 166 knees 129 were improved in one or more of the three parameters - pain at rest, pain on walking and walking ability (Fig 21). Improvement was correlated to correction. Only one fifth of the corrected knees were unimproved as compared to one third of the noncorrected knees. Likewise, the osteotomy was felt by the patients to have impaired the knee in 66 % and 15 % when correction was not achieved or achieved, respectively (Fig 22). 56 patients had pain at rest before the operation and 12 after the operation. Of these, four were corrected and eight uncorrected. This difference was not significant ($0,05 > P > 0,01$).

2. Walking capacity

Data on pre- and postoperative maximum walking capacity was complete for the 107 corrected knees, but for two of the 59 uncorrected knees the data was missing (Table 10). For pain-free walking distance there was missing data on three patients in the corrected group and on two patients in the uncorrected group (Table 11). There was a clear difference in both these parameters between corrected and uncorrected knees (Tables 10 and 11).

3. Knee function

Knee function before and after the operation was expressed in terms of mobility, stability and presence and quality of pain (Fig. 23). Preoperatively there was only one patient in the best subset and 46 in the worst. After the operation these figures were 74 and 11, respectively. After the operation two thirds were pain-free. Of the 107 corrected knees 67 were in the best subset and only two in the worst, while of the 59 uncorrected knees only seven were in the best and nine in the worst subset. Indeed, freedom from pain was achieved five times more frequently in corrected as compared to uncorrected knees* (Fig. 24). Thus, there was a significant correlation between good results and adequate correction of the deformity regarding the patients' subjective statement, maximum walking capacity, pain-free walking distance and knee function, but not concerning pain at rest.

* $P < 0.001$.

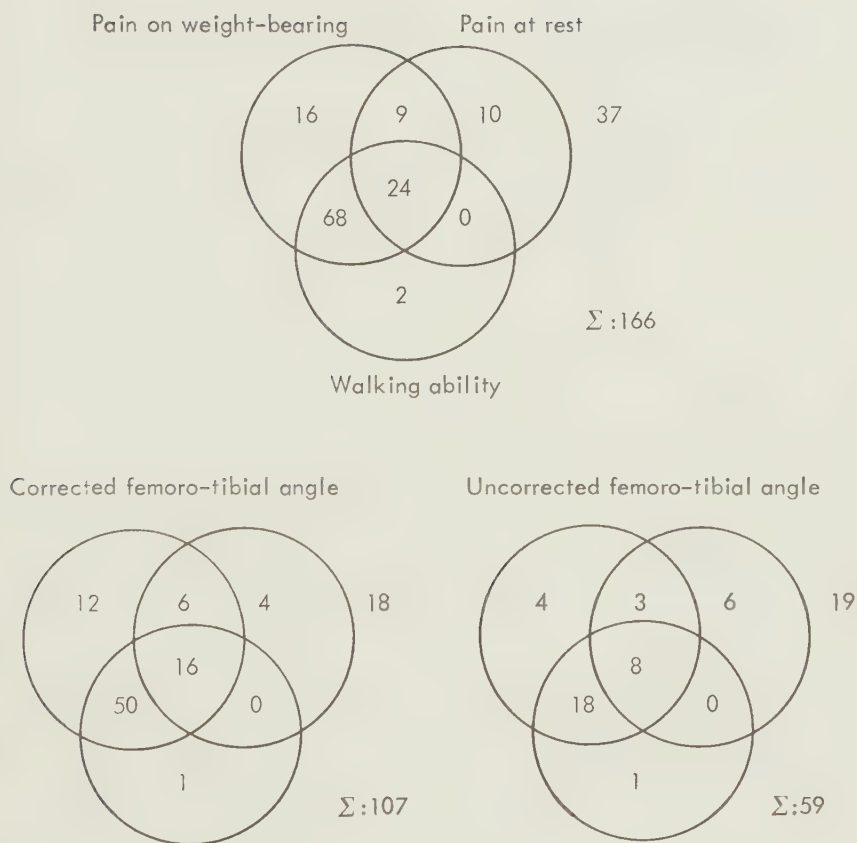


Fig 21. The diagrams show number of knees stated to be improved by osteotomy in the three parameters assessed.

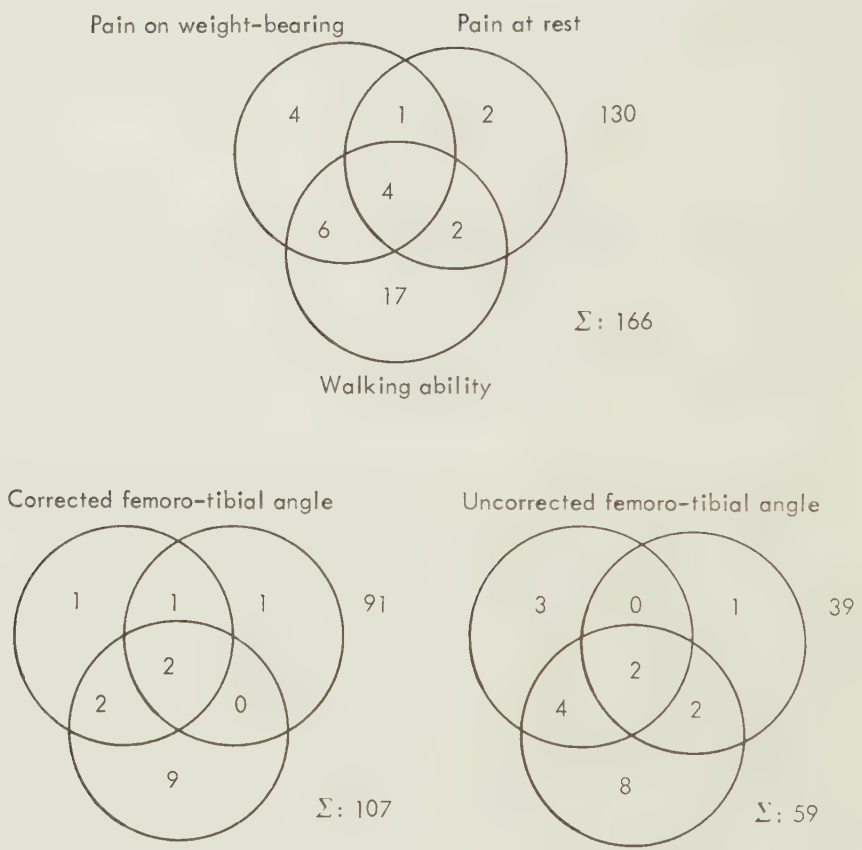


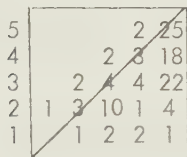
Fig 22. The diagrams show number of knees stated to be impaired by osteotomy in the three parameters assessed.

Table 10. Maximum Walking Capacity Before and After Osteotomy.

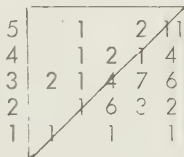
Knees with Corrected Femoro-tibial Angle

Knees with Uncorrected Femoro-tibial Angle

Preop.



1 2 3 4 5 Postop.



1 2 3 4 5

Index of improvement: 0,9 (1,2)

0,5 (0,6)

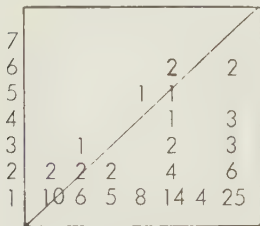
Index within parenthesis calculated after exclusion of cases in best category pre-and postoperatively.

Table 11. Pain-free Walking Distance Before and After Osteotomy.

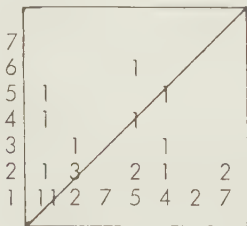
Knees with Corrected Femoro-tibial Angle

Knees with Uncorrected Femoro-tibial Angle

Preop.



1 2 3 4 5 6 7 Postop.



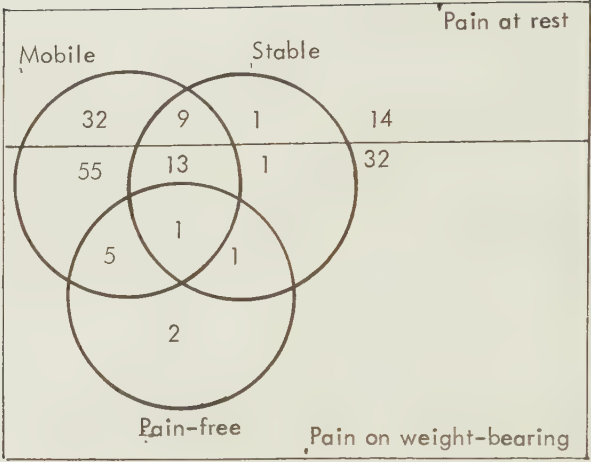
1 2 3 4 5 6 7

Index of improvement: 3,2

1,9

Before osteotomy

$\Sigma: 166$



After osteotomy

$\Sigma: 166$

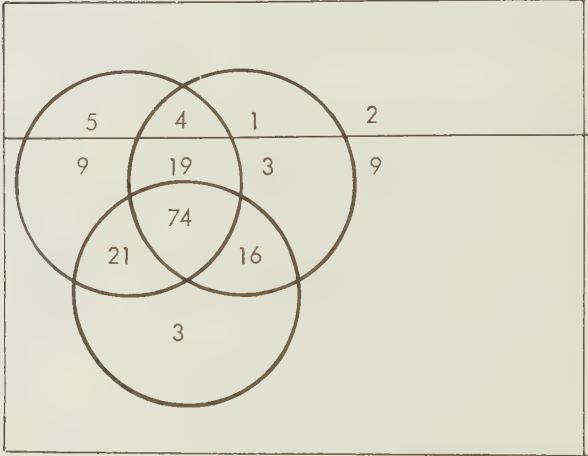


Fig 23. Pre-and postoperative knee function

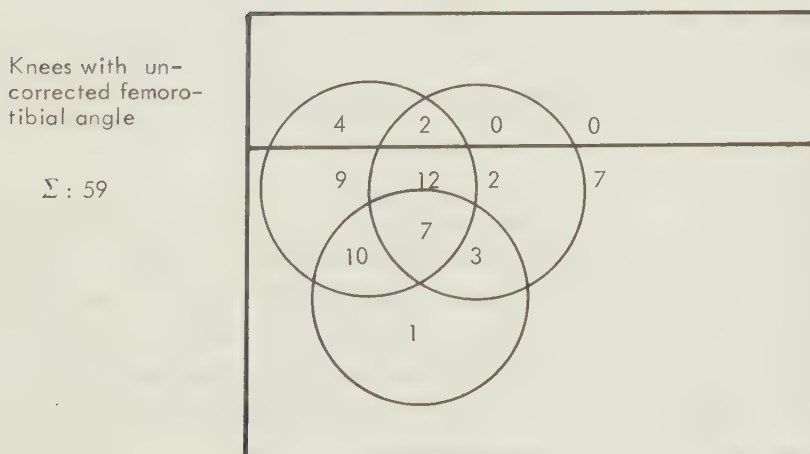
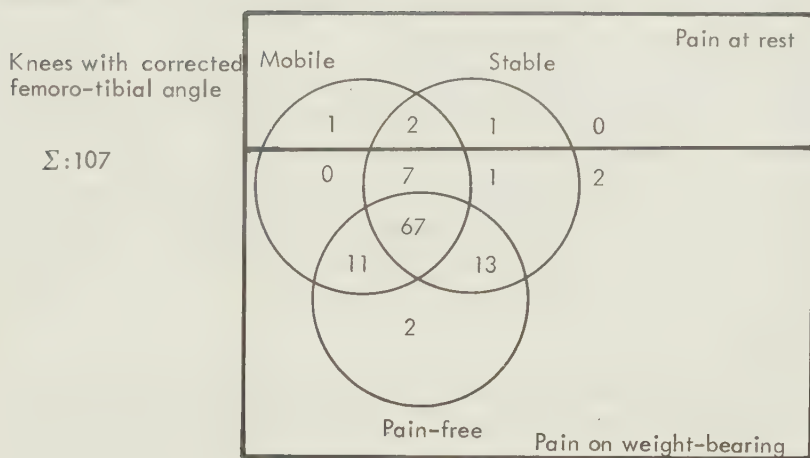


Fig 24. Knee-function correlated to correction of deformity.

E. RESULTS IN DIFFERENT CATEGORIES

1. Type of arthrosis

Patellar arthrosis. Of the 107 corrected knees, 23 had co-existing patellar arthrosis. Regarding function (Fig 25) relatively more knees without as compared to with patellar arthrosis reached the best subset (60 of 84 and 8 of 23, respectively, $0,05 > P > 0,01$). However, the over-all results in freedom from pain, improvement in maximum walking capacity and pain-free walking distance were equal in the two groups (Table 12). Co-existing patellar arthrosis, thus, did not seem to influence the results of the operation to any significant degree.

Medial compared with lateral arthrosis. More (two thirds) of the medial type knees were corrected as compared to the lateral type knees (one half). However, there was little, if any, difference in knee function between the two groups (Fig 26). Thus, there was no difference between the groups in numbers in the best subset or numbers of pain-free knees ($P >$ and $= 0,5$ respectively). Neither was there any difference in maximum walking capacity or pain-free walking distance.

2. Severity of arthrosis

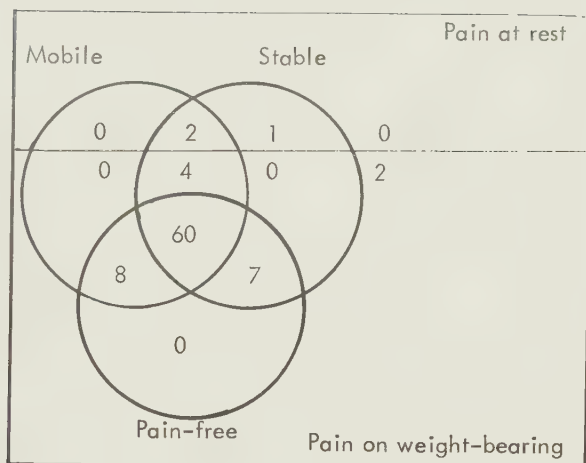
Maximum walking capacity and pain-free walking distance before the operation were analysed with reference to different degrees of radiographic severity. It seemed easier to get correction in knees with mild arthrosis (9 of 10 corrected in grade I) as compared to those with severe arthrosis (5 of 13 corrected in grade V). However, there was no tendency to obtain better results in corrected knees in the milder degrees of arthrosis. On the contrary, the index of improvement seemed to rise with the severity of arthrosis. This was probably a manifestation of the more pronounced impairment in the more severe arthrotic knees – there was more function to be regained, i.e. knees with severe arthrosis had a lower functional class preoperatively.

3. Age

Age did not seem to influence the possibility of deformity correction. There was a good effect on the maximum walking capacity and pain-free walking distance up to 74 years of age. However, the older patients had more severe arthrosis, and, thus, more function to regain. For patients older than 75 the results were less favourable. Of the eleven in whom good correction was achieved only one experienced improved walking capacity, and three increased pain-free walking distance.

Knees without
femoro-patellar
arthrosis

$\Sigma : 84$



Knees with femoro-
patellar arthrosis

$\Sigma : 23$

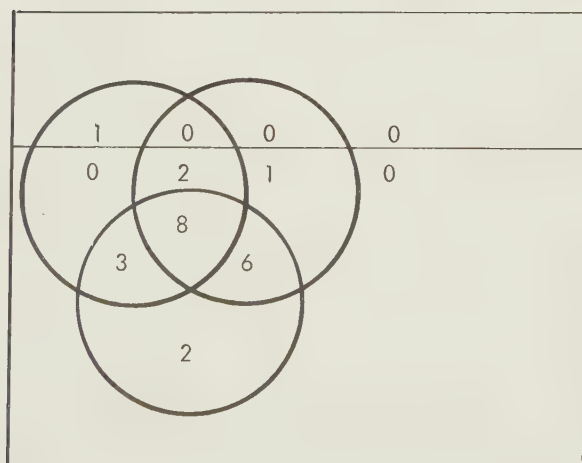
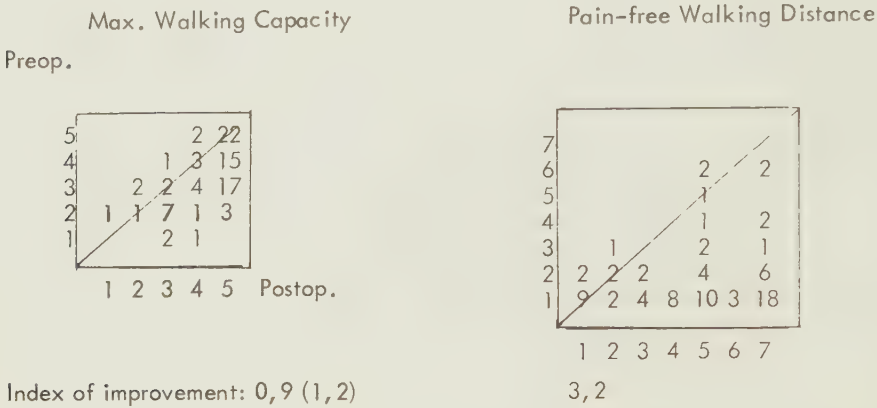


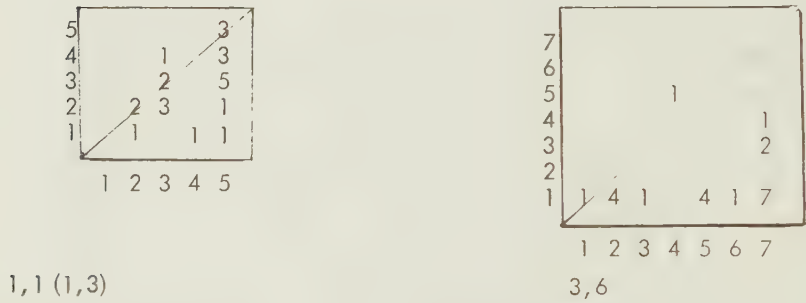
Fig 25. Patellar arthrosis correlated to function after osteotomy.
Corrected femoro-tibial angle.

Table 12. Maximum Walking Capacity and Pain-free Walking Distance Before and After Osteotomy in 107 Knee-joints with Corrected Femoro-tibial Angle (168-180°) with and without Femoro-Patellar Arthrosis.

Knees without Femoro-patellar Arthrosis



Knees with Femoro-patellar Arthrosis

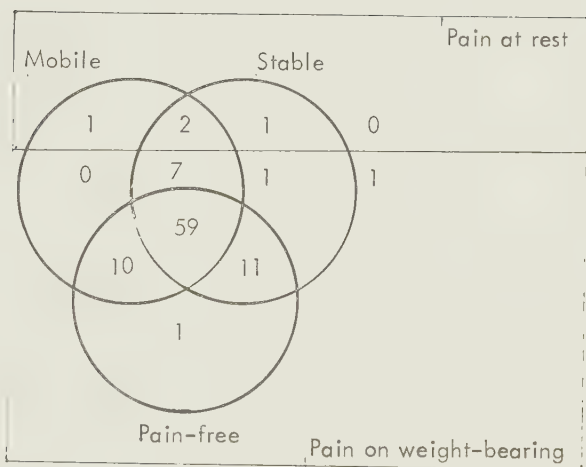


4. Etiology

The posttraumatic group included many corrected knees. However, regarding walking capacity this group was in good shape preoperatively, and much gain was not expected. Gonarthrosis associated with hip disease was the only group that had markedly poor results. Six of these nine knees were corrected, but the maximum walking capacity had increased appreciably in only two cases and the pain-free walking distance was improved in only one.

Medial

$\Sigma : 94$



Lateral

$\Sigma : 12$

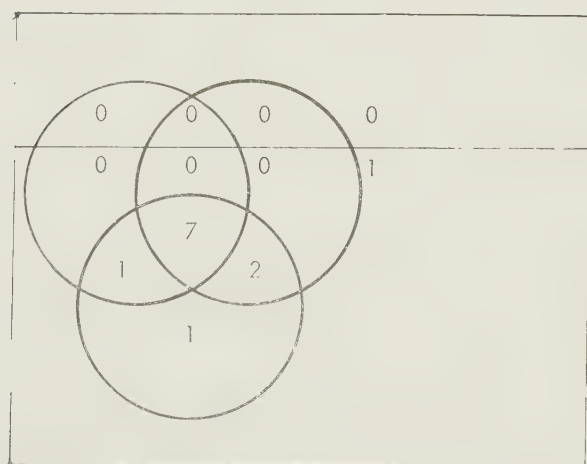


Fig 26. Function after osteotomy by type of arthrosis.
Corrected femoro-tibial angle.

5. Laxity

Laxity has been assigned crucial importance for the results of tibial osteotomy by Artigou (1971) and Coventry (1973). In this series no attempt was made to tighten the collateral ligaments. In 50 knees laxity was noted preoperatively and in 87 postoperatively. In 31 of these laxity was noted both pre- and postoperatively.

In the group with preoperative laxity the maximum walking capacity and pain-free walking distance postoperatively are shown in Table 13 and knee function in Fig 27. Correction was achieved in 30 of these 50 knees. In the corrected group the maximum walking capacity was somewhat less than in the total series, but the pain-free walking distance was equally improved. As regards knee function there were proportionally fewer in the best subset (14 of 30) of knees with notable laxity before operation than knees without notable laxity before operation (53 of 77). As it is highly improbable that knees with laxity would do better by osteotomy than others, a one-tailed significance test was utilized. There was no significant difference according to the Fischer exact probability test ($0,05 > P > 0,01$). The difference concerning pain-freedom was even smaller (25/30 and 68/77, respectively).

The maximum walking capacity and pain-free walking distance pre- and postoperatively in the 87 knees with notable laxity after the osteotomy (Table 14) seemed to be similar to the total series.

Of the 87 knees with laxity postoperatively 52 were corrected. 26 of these 52 knees belonged to the best subset with mobile, stable and pain-free knees as compared to 41 of 55 knees without notable laxity after the operation. This difference was significant ($P < 0,01$). However, in the laxity group 45 were pain-free and in the non-laxity group 48, i.e. no significant difference ($P > 0,05$).

6. Deformity in the sagittal plane

The articular surface of the tibial condyles is normally tilted slightly backwards. In this series the angle TTS was $85 \pm 4^\circ$ preoperatively. The osteotomy regularly results in forward angulation; postoperatively the TTS angle was $95 \pm 9^\circ$. Out of the 14 knees with a TTS angle of 110° or more nine had a good correction in the frontal plane. Ten of the 14 had an appreciable backward thrust at the moment of weight-bearing. The improvement in walking ability, was very slight in the corrected knees, and in the uncorrected knees no improvement was observed in regards to maximum walking capacity and only very slight improvement as regards pain-free walking distance. As regards knee function (Fig 28) (number of knees in the best subset or number of pain-free knees) it did not seem to make any difference whether the TTS

was more or less than 110° as long as the frontal deformity was corrected (4 of 9 and 63 of 98, respectively, and 9 of 9 and 81 of 98, respectively, $P > 0,05$). The four knees with persisting deformities both in the frontal and sagittal planes did very poorly with no improvement in walking ability, and only one of four became pain-free.

Table 13. Maximum Walking Capacity and Pain-free Walking Distance Pre- and Postoperatively in 30 Knees with Notable Laxity Before Osteotomy and Correction of Femoro-tibial Angle.

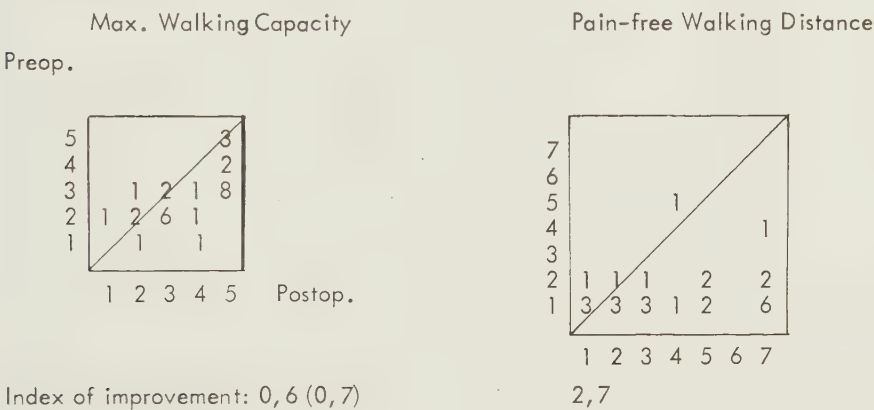
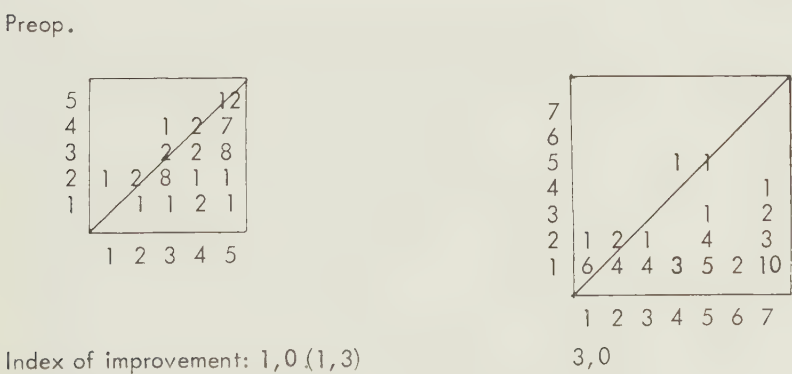
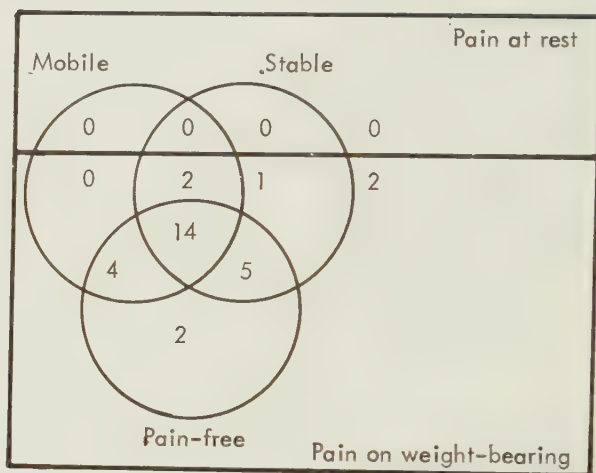


Table 14. Maximum Walking Capacity and Pain-free Walking Distance Pre- and Postoperatively in 52 Knees with a Notable Laxity after Osteotomy and Corrected Femoro-tibial Angle.



Preoperative
laxity

$\Sigma : 30$



Postoperative
laxity

$\Sigma : 52$

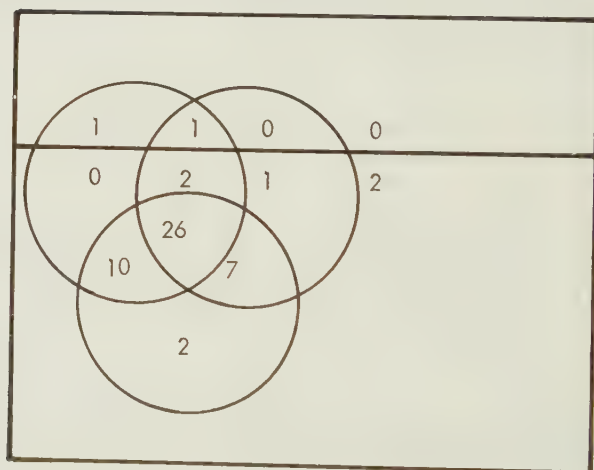


Fig 27. Effect of laxity on knee function after osteotomy.
Corrected femoro-tibial angle.

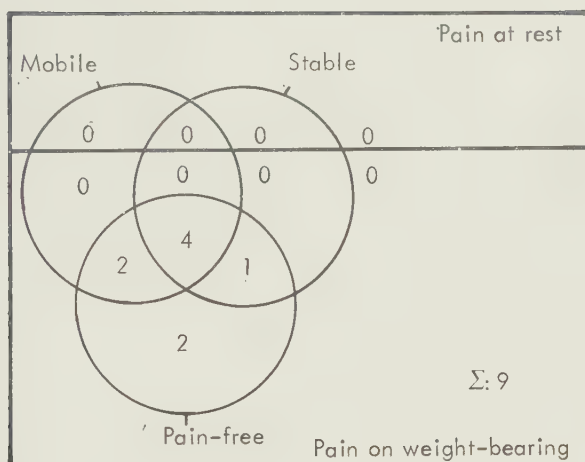


Fig 28. Forward angulation and function after tibial osteotomy

F. RESULTS AFTER REOPERATION

26 reoperations were performed of which 23 belonged to the follow-up series. Of these, reoperation was performed because of pseudarthrosis in five knees, under-correction in 13, overcorrection in four and a recurvatum deformity in one knee. 14 finally achieved correction and 9 had persisting deformity. Of the five operated on for pseudarthrosis four belonged to the last group. The final results in the corrected knees were comparable to the total material regarding walking capacity, pain-free walking distance and knee function, but strikingly poor for the uncorrected knees. This was the only group in the series that had a negative index of improvement for maximum walking capacity. Of the nine knees in this group only three were pain-free, and none belonged to the best subset of pain-free, stable and mobile knees.

IV. DISCUSSION

Until recently effective treatment of gonarthrosis was restricted to arthrodesis. However, gonarthrosis is a disease of the old and is often bilateral. Arthrodesis was therefore not acceptable in most cases of gonarthrosis. Furthermore, arthrodesis was based on the misunderstanding that the arthrotic process involved the entire knee joint. On the contrary it is now known that the disease, although progressive, is usually confined to only one of the two femoro-tibial articulations (Hernborg 1974) Ahlbäck 1968, Bauer and Smith 1969). Osteotomy for treatment of gonarthrosis was therefore introduced on the rationale that correction of the secondary deformity would transfer weight-bearing to more normal articular cartilage.

A. EFFECT OF OSTEOTOMY

It is still debated in what way osteotomy relieves pain. Earlier reports have demonstrated the correlation between good results and correction of the deformity (Ramadier 1965, Bauer et al. 1969, Artigou 1971). Initially good results of osteotomy also hold up with time (Debeyre and Patte 1966, Coventry 1973). This correlation between correction of deformity and results in terms of walking ability and pain on weight-bearing was confirmed in this series. These observations provide evidence that unloading of the over-loaded articulation is an important factor. Further evidence for this view has been given by Koshino and Ranawat (1972) who made ^{85}Sr scintimetry in knees with medial type arthrosis before and after osteotomy. The high up-take of ^{85}Sr at the medial articulation decreased markedly after osteotomy in corrected knees but not in uncorrected knees. These findings also speak against the theory of osteotomy working mainly through decongestion of pathologically dilated venous sinusoids in the juxta-articular bone as claimed by Helal (1965). However, in this series one third of the patients had pain at rest preoperatively, and postoperatively there was no clear correlation between correction of deformity and disappearance of pain. This observation confirmed Appel and Friberg's findings (1972). It is indeed possible that rest pain in arthrosis is due to venous abnormalities secondary to the arthrotic process as claimed by Hulth (1958), Phillips (1966) and Lynch (1973).

B. OPERATIVE TECHNIQUE AND POSTOPERATIVE MANAGEMENT

The technique with the closing wedge osteotomy proximal to the tibial tuberosity suggested by Bouillett and Van Gaver (1961) and strongly recommended by Coventry (1965) has been widely accepted in recent years (Jackson 1973). The postoperative

regimen is also rather uniform with at least partial weight-bearing in a cylinder cast for 5-6 weeks (Bauer et al. 1969, Coventry 1973).

One of the great advantages with this method is the possibility of early mobilization; most of the patients in this series left hospital within 14 days. Artigou (1971) on the other hand, who used principally the same technique kept his patients in hospital 5-6 months.

C. RESULTS

1. Complications

In this material many complications were recorded, most of them without clinical significance, however. There were no deaths secondary to operation, no deep infection as was reported by Artigou (1971) in three cases and by Bauer et al. (1969) and no vascular complications leading to amputation as was reported by Coventry (1973). High tibial osteotomy must be regarded as a rather safe procedure which is of importance in setting the indications.

a. Non-union

Delayed union was reported by Jackson et al. (1969) in three patients requiring bone grafting after osteotomy at the level of the tibial tuberosity and by Bauer et al. (1969) after high tibial osteotomy in one case. Artigou (1971) reported five cases of delayed unions and eight of pseudarthrosis. Five of the latter cases occurred among 17 cases following V-shaped osteotomy; this method was abandoned for this reason. Coventry (1973) did not record any case of delayed union or pseudarthrosis. The period of time to radiographic healing was not recorded in this series because radiographic healing is not needed for weight-bearing. Indeed the process of healing in cancellous bone involves simultaneous bone resorption and formation which may radiographically simulate pseudarthrosis (Fig 14). However, eight cases of true pseudarthrosis were observed here. One of these cases could be attributed to renal failure but in the other cases no obvious reason could be found. Possibly inappropriate plaster techniques and/or too early full weight-bearing played a part.

b. Thromboembolism

Cohen and associates (1973) performed phlebograms pre- and postoperatively in 35 consecutive patients who underwent knee surgery. They found 20 patients with signs of fresh thrombosis. Hjelmstedt et al. (1963) found older women with fracture of the lower leg to be a high-risk group for deep venous thrombosis. It is therefore rather

astonishing that not a single case of lethal pulmonary embolism has been reported following tibial osteotomy for gonarthrosis.

Artigou (1971) noted a frequency of 6 % of thromboembolism using prophylactic anti-coagulant therapy and Coventry (1973) had three of 71 patients rehospitalized because of thrombophlebitis. In the present series the only thrombo-prophylactic method has been pre- and postoperative active exercises and early mobilization. The frequency of definite signs of pulmonary embolism and/or deep venous thrombosis was 4 %, i.e. not higher than in those series where preventive anticoagulant drug therapy was used routinely. However, in all these materials the diagnosis was based on clinical findings. In recent years massive evidence has been published to show that clinical diagnosis of thrombosis gives considerable over- and underdiagnosis (Phillips 1963, Haeger 1965, Arnoldi 1967). There must certainly be many cases with subclinical forms of thrombosis after osteotomy which are potentially life-threatening even though no deaths have been reported thus far. It should therefore be seriously considered if prophylactic anti-thrombotic treatment shall be instituted. Treatment with dicumarine derivatives is too complicated in this form of short-hospital-stay surgery but it has recently been reported that peroperative infusion of dextran reduces the incidence of postoperative thromboembolic complication in abdominal surgery by about 50 % (Janssen 1972) and in fractures of the hip (Ahlberg et al. 1967).

c. Peroneal palsy

Sporadic cases of peroneal palsy complication have been reported by Coventry (1965), Devas (1969), Goerttler and Debrunner (1969) and Artigou (1971). In his later report Coventry (1973) had no such complications which he ascribes to his method of using a Robert Jones cotton dressing with a posterior plaster splint the first eight days after operation. Weakness of dorsiflexion of the foot was observed in no less than 10 % of the operations in this series. In all but two cases there was a time lag before onset which suggested that pressure from the plaster combined with postoperative edema was important. There were, however, cases with very late onset associated with recurvation in the knee which could be ascribed to stretching of the peroneal nerve, clearly proved in one case. The prognosis was good, however, and only four patients had any persisting symptoms at the time of follow-up. Steel and associates (1971) have attributed signs of sensory loss and weakness of dorsiflexion of the foot after tibial osteotomy for genu varum or valgum in children to compression of the anterior tibial artery. Possibly the same mechanism may obtain in adults.

d. Other complications

Fracture of the proximal tibia during the operation occurred but once in this series but it was associated with loss of correction as was described by Bauer et al. (1969). This complication is best avoided by placing the osteotomy at least 2 cm distal to the joint and by leaving at most a thin bridge of cortex at the apex of the wedge so that the leg can be brought into correction with minimal or no force.

Displacement medially of the proximal fragment (Bauer et al. 1969) was avoided in this series, but in some cases there was a marked displacement forward with angulation of the tibia; in most cases this had little clinical significance. (Fig 18, s.39)

All complications considered the high tibial osteotomy can still be regarded a rather safe procedure.

2. Mobility

Perhaps for historical reasons patients confronted with an orthopaedic operation very often hesitate for fear of joint stiffness. The high tibial osteotomy implies practically no such risk. In the material of Bauer et al. (1969) 20 knees were preoperatively classified as not mobile but only nine postoperatively. Coventry (1973) stated that the osteotomy does not "lead to any consistent change of mobility but a few patients lost 10-20° of flexion". The best results in this respect have been reported by Artigou (1971) who stated that there was more than 90 % change of regaining at least the preoperative mobility and 20 % chance of getting even better mobility. Artigou's figures are possibly explained by the fact that his patients were rehabilitated in hospital for three to five months postoperatively. In the present material in which the patients rarely stayed in hospital for more than 2 weeks, there was no overall change in total range of motion. 31 patients had, however, lost more than 20° in flexion. Earlier and more frequent use of manipulation of the knee would very probably have decreased this number.

3. Correction

Currently used methods have been rather poor at achieving the desired correction of the deformity. Only two thirds of the knees in this series got the desired angle postoperatively and this corresponds to Bauer et al. (1969) using the same method. Artigou (1971) had only 55 % corrected knees when calculating the angle on radiograms obtained in supine position and using four different methods of performing the osteotomy. Coventry (1973), calculating his angle on radiograms obtained in standing position and aiming at 5° of over-correction, seemed to get the desired correction in all

patients. In this series 50% of the undercorrected varus knees were obvious at the first postoperative radiogram. This calls for better methods of calculating and obtaining the desired correction. To get a correct view of the biomechanical status of the leg, radiograms of the entire leg in standing position should be obtained in a defined frontal plane.

The situation is more complicated in valgus deformity. Shoji and Insall (1973) found far inferior result in valgus cases as compared to the Bauer et al. (1969) series of knees with predominantly varus deformity. They correlated this to the degree of tibial tilting which they recommended not to exceed 15° and to a concomitant medial ligament laxity which causes subluxation. For the same reason Coventry (1973) recommends lower femur osteotomy in cases with valgus deformity more than $12-15^{\circ}$ with the plane of the joint line inclined more than 10° . Artigou (1971) points out the importance of attrition of the lateral femoral condyle as the cause of the inclination of the joint line and he also recommends femoral osteotomy in genu valgum. The observations in this series supported these opinions in that only 12 of 24 valgus knees were corrected and all others were over-corrected. It seems evident that in valgus knees there are two factors that must be mastered, (1) the collateral ligamentous instability with medial gaping and, (2) the inclination of the joint line. It is impossible to get a balanced knee if the side-to-side instability in the knee exceeds 12° . Under-correction can only lead to persisting weight-bearing on the lateral condyle and even slight over-correction leads to weight-bearing on the medial condyle which in turn causes the knee to swing over into varus. These extremes must be assessed preoperatively with the aid of radiograms in provoked varus and valgus position and measurements of the angles of the tangents of the tibial and femoral articular surfaces. If the difference between these angles in the extreme positions exceeds 12° it seems impossible to achieve balance with a tibial osteotomy. However, excessive angulation is often associated with large attrition laterally and when this predominantly involves the femoral condyle the joint line will be inclined after correction. The joint line inclination is best expressed as the angle between the tibial shaft and the tangent to the femoral condyles. The postoperative angle can then be calculated by adding the preoperative value to the calculated desired angle of correction. The inclination of the joint line is then this angle minus 90° . If the result is more than 10° the osteotomy should be made in the femur rather than in the tibia.

4. Effect on symptoms

In different types of arthrosis there was no difference in this material between medial and lateral femoro-tibial arthrosis provided the deformity was corrected as was observed also by Artigou (1971). Coventry (1973) did not distinguish between lateral and medial arthrosis in his results but he recommended femoral osteotomy to be performed rather than accepting tilting of the joint line. Shoji and Insall (1973) found far inferior results in valgus knees but in their material this may have been due to deficient correction.

A co-existent patellar arthrosis had no influence on the results in this series as was also found by Artigou (1971) and Coventry (1973).

Regarding the severity of arthrosis Coventry (1973) stated that the results were inferior in more pronounced arthrosis; he did not define his classification, however. In the present series it seemed easier to correct cases belonging to grade I than grade V. Results in other grades were comparable except in cases with subluxation. For general reasons, however, osteotomy should preferably be performed early rather than late.

In this series, the results of osteotomy in different age groups were fully comparable up to 75 years. Older patients in this series did rather poorly. This factor has not been analysed in earlier series. One of the disadvantages with osteotomy is the rather long rehabilitation period. Many patients told that it took them 6-12 months to regain their preoperative strength. This may have been a manifestation of the high age of the patients in this series.

Etiology of arthrosis has been regarded by Artigou (1971) and Coventry (1973) and both claim to have more favourable results in posttraumatic cases. In this series, also, the result were good in these cases but they were all in a good functional class already preoperatively. Results in arthrosis of other causes were rather uniform except in cases associated with hip disease which did not do well. When hip symptoms dominate, the hip should be handled first and only later the knee.

The crucial importance of laxity reported by Artigou (1971) and Coventry (1973) was not confirmed here. Only when the laxity was so great as to cause subluxation were the results less favourable.

5. Reoperations

In reoperations because of pseudarthrosis the results were poor because the deformity was usually not corrected. In order to obtain union compression devices are recommended for reoperations because of pseudarthrosis. Even with early mobilization and cast removal at six weeks the convalescence period is long after osteotomy. This must be considered when reoperations are indicated, especially in older patients, so as not to compromise an unduly long part of their residual life span.

D. CHOICE OF OPERATION FOR GONARTHROSIS

In the past the operative solution to gonarthrosis was to perform an arthrodesis. Although Charnley (1953) described good results in certain patients with bilateral arthrodesis, this procedure is at most suitable only for young individuals with involvement of one knee joint. In other situations it can only be used as a salvage procedure after failures of other operations. The problem of the painful hip has in largely been solved by the introduction of total endoprosthetic arthroplasty (Charnley 1972). Similarly, much work has been devoted to development of the total knee. However, compared to the hip joint the problems for the knee joint are much greater. Biomechanically the knee is more complicated. There is less soft tissue to cover the endoprosthesis. In the hip joint there is freedom of movement in all directions whereas in the knee movement takes place in a restricted arc in one plane, with high demands on the anchoring of the prosthesis. Many types of total knees have been constructed but it is significant that much emphasis is put on the possibility of performing an arthrodesis as salvage procedure. An attempt will be made here to define the indications for the total knee as compared to osteotomy in gonarthrosis.

Hinged prosthesis was pioneered by Walldius (1953 and 1969) who still does not use fixation with acrylic cement as do Shier (1965) and the French Guépar group (1973). The experience with the non-hinge prosthesis is rather wide in rheumatoid arthritis but not in osteoarthritis (Jones 1973, Habermann et al. 1973, Freeman et al 1973, Phillips 1973, Mazas et al. 1973). Common features in all reports are the incidence of serious complications in the form of deep infection, loosening of the prosthesis and fractures. There have also been described cases of thromboembolic symptoms and cardio-pulmonary collapse at the moment of introducing the stems into the medullary cavity or loosening of the tourniquet (Freeman et al 1973, Mazas et al 1973). The hinge prosthesis can at present be recommended only for highly disabled individuals with multiple joint involvement.

Many types of non-hinged total knee endo-prostheses are now being developed. Common features to most of them is the use of metal to high density polyethylene articulation and fixation with methylmetacrylate. Gunstone (1973) has described his polycentric knee, used predominantly in rheumatoid arthritis with good results. The Freeman-Swanson prosthesis (Freeman 1973) has also predominantly been used for rheumatoid arthritis so far. In osteoarthritis experience at present favours the geometric total knee.

Coventry et al. (1973) have reported on two years observations in 307 insertions of this prosthesis of which 128 for primary and 24 for posttraumatic gonarthrosis. They found two wound sloughs and two superficial wound infections - both healed, and they had no deep infections. Three patients had transient peroneal palsy and three persisting disabling pain. Two patients had significant thromboembolic phenomena. Two patients had a persisting disabling valgus deformity of which one could be corrected by reoperation. Their result as regards pain and walking abilities were promising although some soft tissue discomfort with some aching usually persisted.

The advantage with the total knee replacement is that the element of bone healing is eliminated; the convalescent period is short which is of great importance in old patients. The complications are however of a higher dignity than those in osteotomy, above all infection - very high standards of aseptic condition are essential. Jackson et al. (1973) summarizing six years experience with arthroplasty, felt "that artificial joints should be inserted only in severely crippled patients. There is probably little place for their use in osteoarthritic knees which in most cases can be dealt by osteotomy". At present the indications for total knee arthroplasty in gonarthrosis should be limited to cases not suitable for osteotomy and then in most cases a non-hinged type of prosthesis should be chosen.

V. CONCLUSIONS

- 1) High tibial osteotomy is at present the best method for treatment for most cases of uni-articular femoro-tibial arthrosis.
- 2) The results of tibial osteotomy are correlated to the correction of the deformity as regards walking ability and pain on weight-bearing.
- 3) The osteotomy should be performed early in the course of the disease.
- 4) In lateral arthrosis with pronounced valgus deformity, especially with medial laxity, low femoral osteotomy is recommended.
- 5) In hip disease with gonarthrosis the hip must be corrected first.
- 6) The total knee endoprosthesis should be considered in patients over 75 years of age, in knees with subluxation or when osteotomy has failed; a non-hinge total knee should then be chosen.

VI. SUMMARY

The purpose of this investigation was to analyse the effect of high tibial osteotomy in different kinds, types and degrees of gonarthrosis, to assess the correlation between the results of operation and the correction of the deformity, and, finally, to define the indications of high tibial osteotomy in gonarthrosis as compared to the total endoprosthesis.

Gonarthrosis was defined here as osteoarthrosis of the knee, either primary, or secondary to non-inflammatory conditions.

The investigation involved a prospective analysis of a consecutive series of 162 patients with a mean age of 65 years and with 176 operated knees, during a 2-year period. A follow-up examination was made one year or more postoperatively. The follow-up material consisted of 166 knees in 152 patients.

The majority of the knees, or 85 %, had medial type femoro-tibial arthrosis with varus deformity and 15% lateral type with valgus deformity. The severity of articular cartilage and bone involvement was classified in five grades. Two thirds were grade three or worse, i.e. the articular cartilage of the involved femoro-tibial articulation was completely destroyed, bone attrition was moderate to severe and in some knees subluxation occurred on weight-bearing.

In two thirds, or 139 of the knees, the arthrosis was idiopathic (primary), with associated pyrophosphate synovitis in 11, in 19 posttraumatic, in 5 secondary to osteonecrosis and in 10 it was associated with hip disease.

The osteotomy was made under a tourniquet as a closing wedge just proximal to the tibial tuberosity. The knee was immobilized in plaster for six weeks with full or partial weight-bearing allowed. The patients were hospitalized on average 18 days, including readmissions for manipulation, reoperation etc.

There were no deaths and no cases of deep infection associated with the operation. Major complications observed were 8 cases of non-union, 5 cases of thromboembolism and 16 cases of, usually transient, peroneal palsy.

The operation caused loss of mobility by 20° or more in 31 knees but average there was no loss of mobility, partly because some forward angulation nearly always occurred of the osteotomy. Adequate correction of the deformity was achieved in 65 % of the

knees. Unsatisfactory correction was mainly due to undercorrection in the varus knees and always to overcorrection in the valgus knees. In half of the uncorrected knees the immediate postoperative position in the osteotomy was unacceptable and in the others correction was usually lost after the plaster was removed.

Out of the 166 knees 129 were improved in one or more of the three parameters – pain at rest, pain on walking and walking ability. Improvement was correlated to correction. Only one fifth of the corrected knees were unimproved as compared to one third of the non-corrected knees. Likewise, the osteotomy was felt by the patients to have impaired the knee in 66 % and 15 % when correction was not achieved or achieved, respectively. Pain at rest was present in one third preoperatively and usually relieved by the operation, seemingly unrelated to correction of the deformity.

Knee function before and after the operation was expressed in terms of mobility, stability and presence and quality of pain. Preoperatively there was only one patient in the best subset and 46 in the worst. After the operation these figures were 74 and 11, respectively. After the operation two thirds were pain-free. Of the 107 corrected knees 67 were in the best subset and only two in the worst, while of the 59 uncorrected knees only seven were in the best and nine in the worst subset. Indeed, freedom from pain was achieved five times more frequently in corrected as compared to uncorrected knees. Thus, there was a significant correlation between good results and adequate correction of the deformity regarding the patients' subjective statement, maximum walking capacity, pain-free walking distance and knee function, but not concerning pain at rest.

Co-existing patello-femoral arthrosis did not seem to influence the results of the operation to any significant degree. – It seemed easier to obtain correction in knees with relatively mild as compared to more severe degree of arthrosis. On the other hand, there was more function to be regained in cases of severe gonarthrosis. – In patients older than 75 the results were generally not favourable. – In gonarthrosis associated with hip disease the results were markedly poor. – Preoperative ligamentous laxity seemed to be associated with poor postoperative results only when the condition was so severe as to have caused subluxation.

Reoperations were performed in 26 knees because of non-union or under- or over-correction. In those that were eventually corrected the results were largely favourable but in those that stayed uncorrected strikingly poor.

It was concluded that the high tibial osteotomy is the best method of treatment of most cases of uni-articular femoro-tibial arthrosis. The preoperative radiographic assessment of the deformity and the operative technique are highly important as the results of the operation are correlated to correction of deformity. In pronounced valgus deformity the osteotomy should be performed on the femoral rather than on the tibial side of the joint. In hip disease with gonarthrosis the hip should be correct first. The total knee endoprosthesis should be considered in patients over 75, in knees with subluxation or when osteotomy has failed.

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